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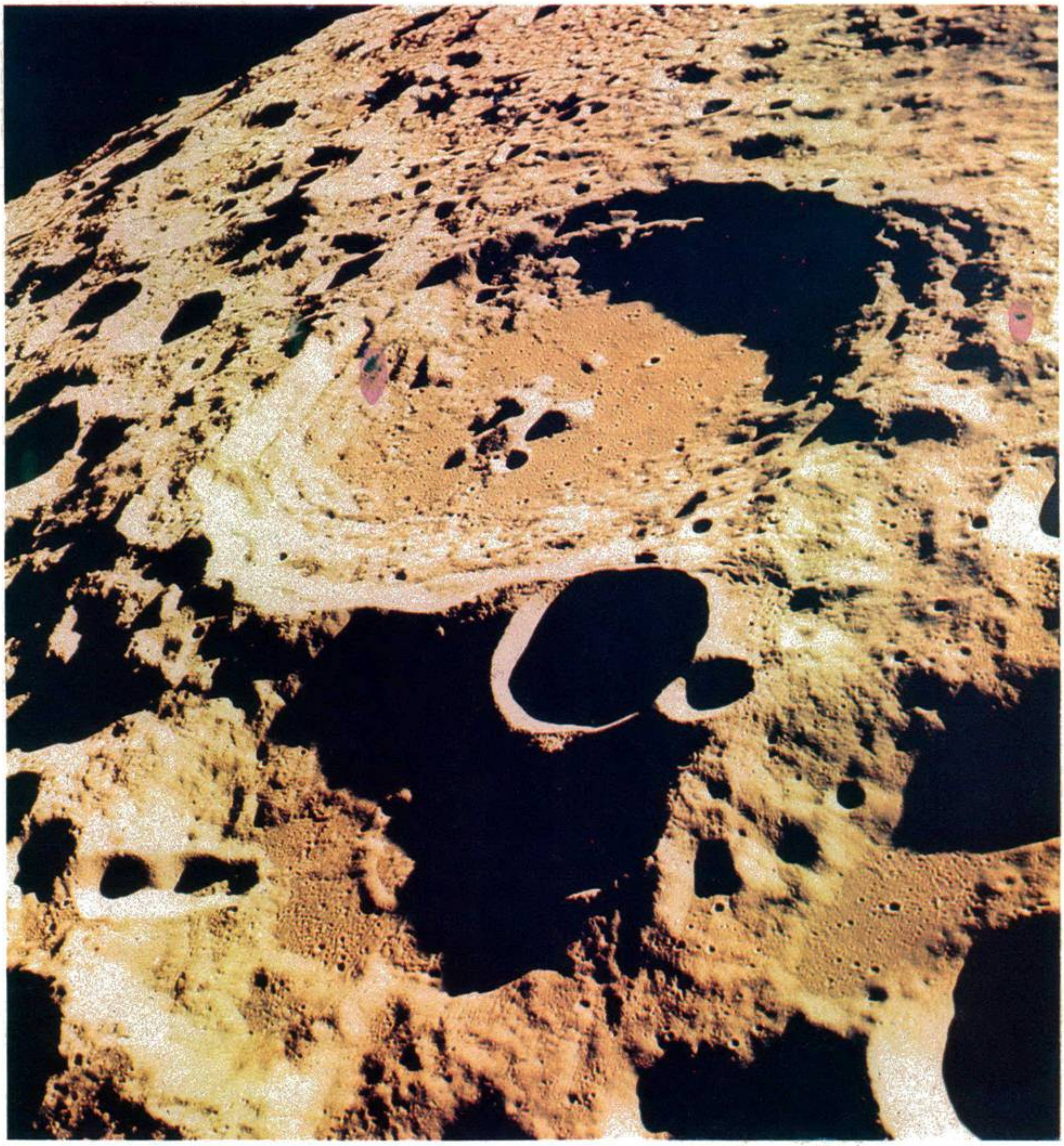

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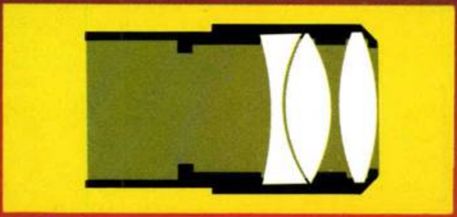

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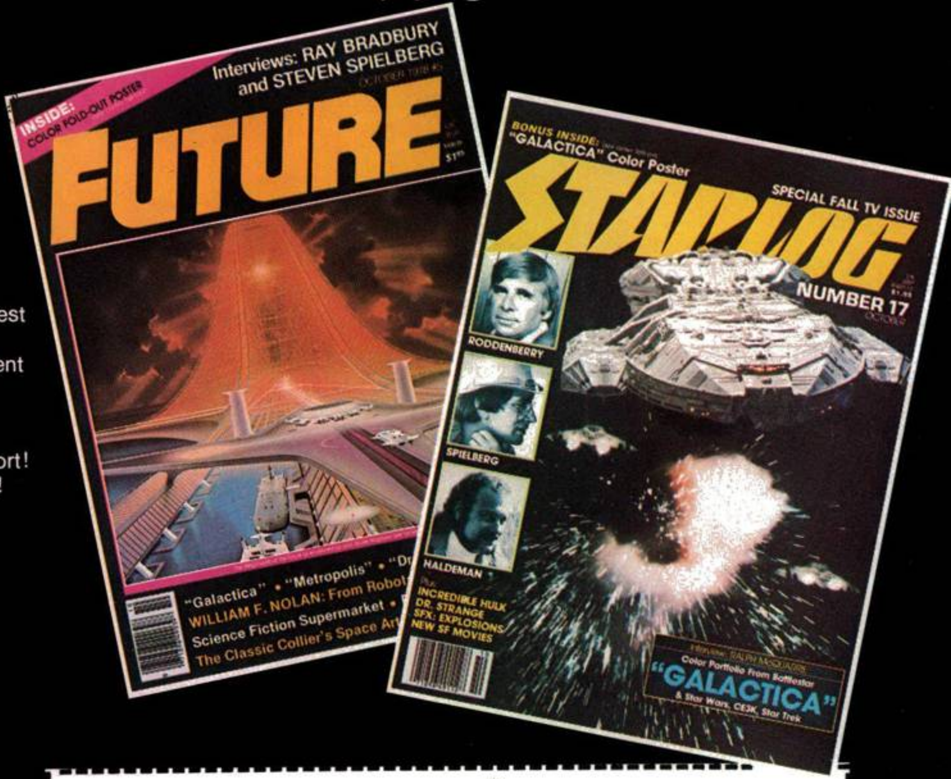
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BEHIND THE SCENES

If you check the masthead this month, you'll see we've added two new associate editors to ASTRONOMY's staff: Robert Burnham and Dewey Schwartzenburg. Both Robert and Dewey came through our grueling editorial questionnaire with flying colors, and we invited them to join our staff after each had paid a visit to our office in Milwaukee.

Robert Burnham has an unusual background — he's a professional librarian! He got his degree in the field after working for several years in the Toronto metropolitan science library (where he answered all incoming astronomical questions).

Left to right: Dewey Schwartzenburg, Richard Berry and Robert Burnham stand in front of the press at E. F. Schmidt where ASTRONOMY is printed. On press was the October 1978 issue.

He has long been an active observer and is familiar with an impressive array of different instruments commonly used by astronomy enthusiasts. We'll be drawing on his expertise, especially through his guidance of the Sky Almanac and Gazer's Gazette departments. We'll also be using his library knowledge in Astronomy Reviews, and more directly, to sort through and re-organize the magazine's reference library and picture files.

On his own, Robert is an avid book collector, and even owns and uses a 750 pound printing press — sign of a true bibliophile. He's also a very fine photographer, and will lend his practiced eye to choosing photos for ASTRONOMY!

Robert has a strong desire to involve people in active observing, and plans to have a number of features showing how easy and fun it is to start making your own observations.

Dewey Schwartzenburg comes to us directly from the University of Notre Dame, where he has just completed the requirements for a Ph.D degree in — of all things — theology! Dewey is also an Episcopal priest, and has served parishes in both Massachusetts and Indiana. This does not mean that ASTRONOMY will begin to cover another category of "heavenly matters", though — for Dewey also has an especially strong background in science and astronomy. In fact, he holds an A.B. degree in astrophysics from Harvard College!

Dewey has also been actively involved for many years in amateur astronomy. One of the founders of the Shreveport (La.) Astronomical Society, he later served two terms as its president. During that period the society mounted two ambitious projects — construction of an astronomical observatory with a 16 inch reflector as the main instrument, and the provision of a planetarium for the city of Shreveport.

In his parish ministry he was noted for such off-beat programs as a special youth group expedition to observe a solar eclipse! And his Ph.D in theology includes a minor in history and philosophy of science, with special emphasis on astronomy. Among many other responsibilities, Dewey will be in charge of our Astro-News department. Dewey is enthusiastic about the opportunity to exercise his talents on behalf of what he calls his "first love" — astronomy.

We're sure ASTRONOMY will be a better magazine with Robert and Dewey. Each of them, in addition to his "own" areas, will work with me writing and editing feature articles, Stellar Frontiers, the observing departments and, of course, some special projects you'll hear about later!

Richard Berry

Richard Berry
Editor

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Cover

How far we have come from the earliest days of space exploration becomes clear only in looking back. Our cover picture, taken by Apollo 11 astronauts during the first flight to land on the moon, shows Daedalus, a 50 mile (80km) crater at nearly the center of the moon's far side. So much imagined then has now come true — Vikings to Mars, Pioneer to Jupiter, this month's twin Venus missions and the sophisticated Voyager probes now heading for Jupiter — that we may almost forget the crude termination of the Apollo program, cutbacks in the Space Shuttle program and cancellations of other planetary missions. Yet we shouldn't forget. Without public enthusiasm and financial support, the American era of space exploration may be drawing to a close. NASA Apollo 11 photograph AS11-44-6611.

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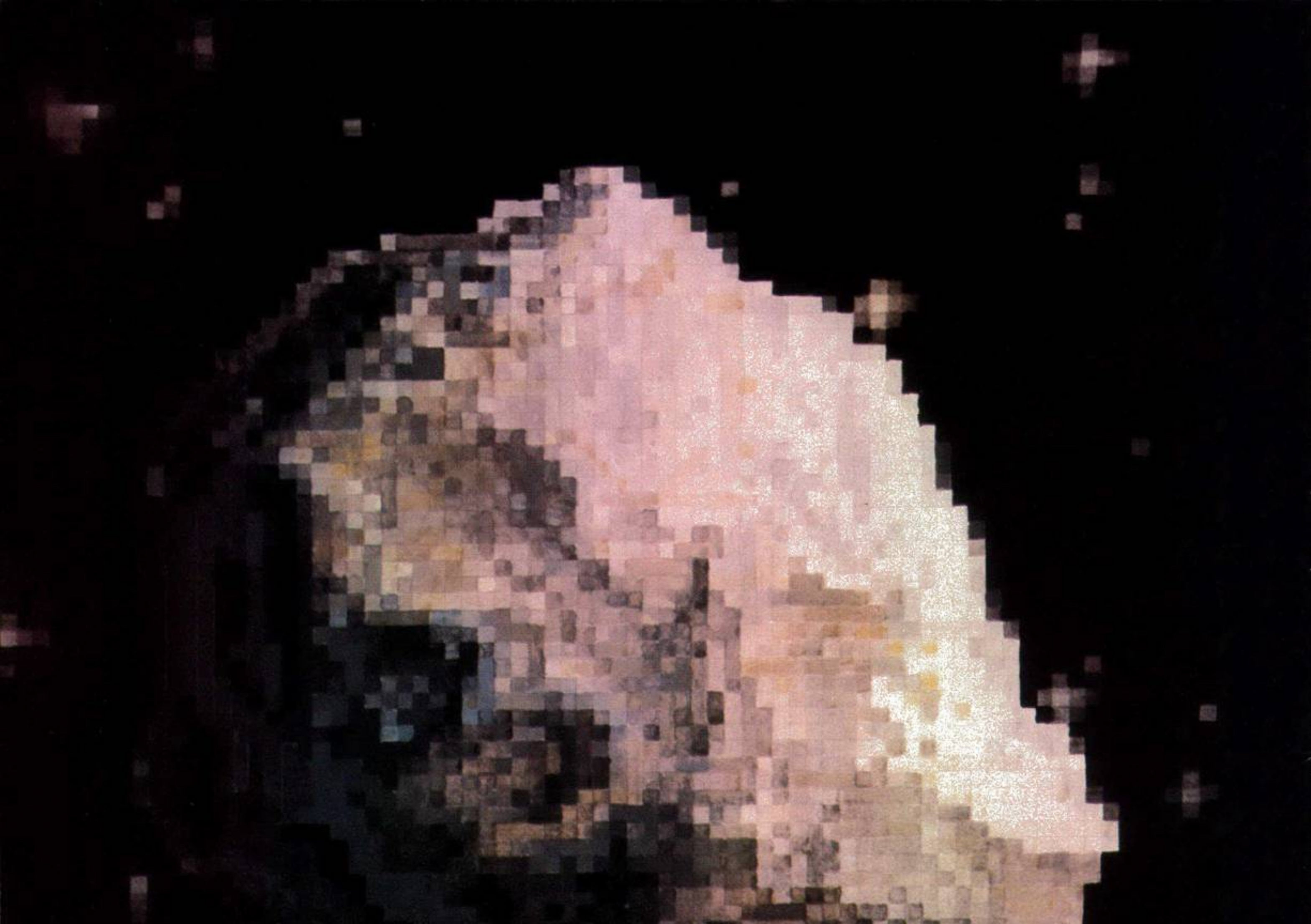
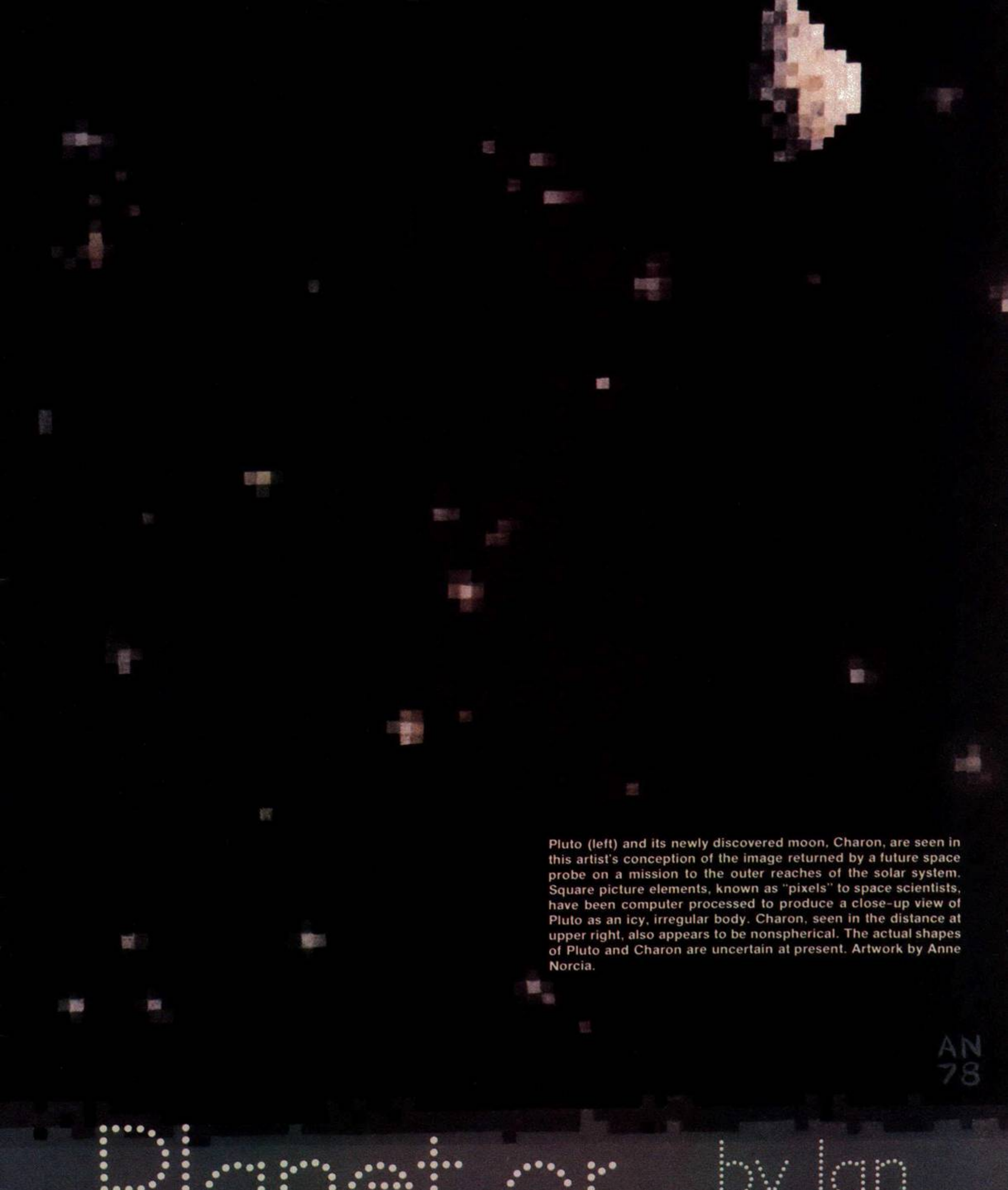


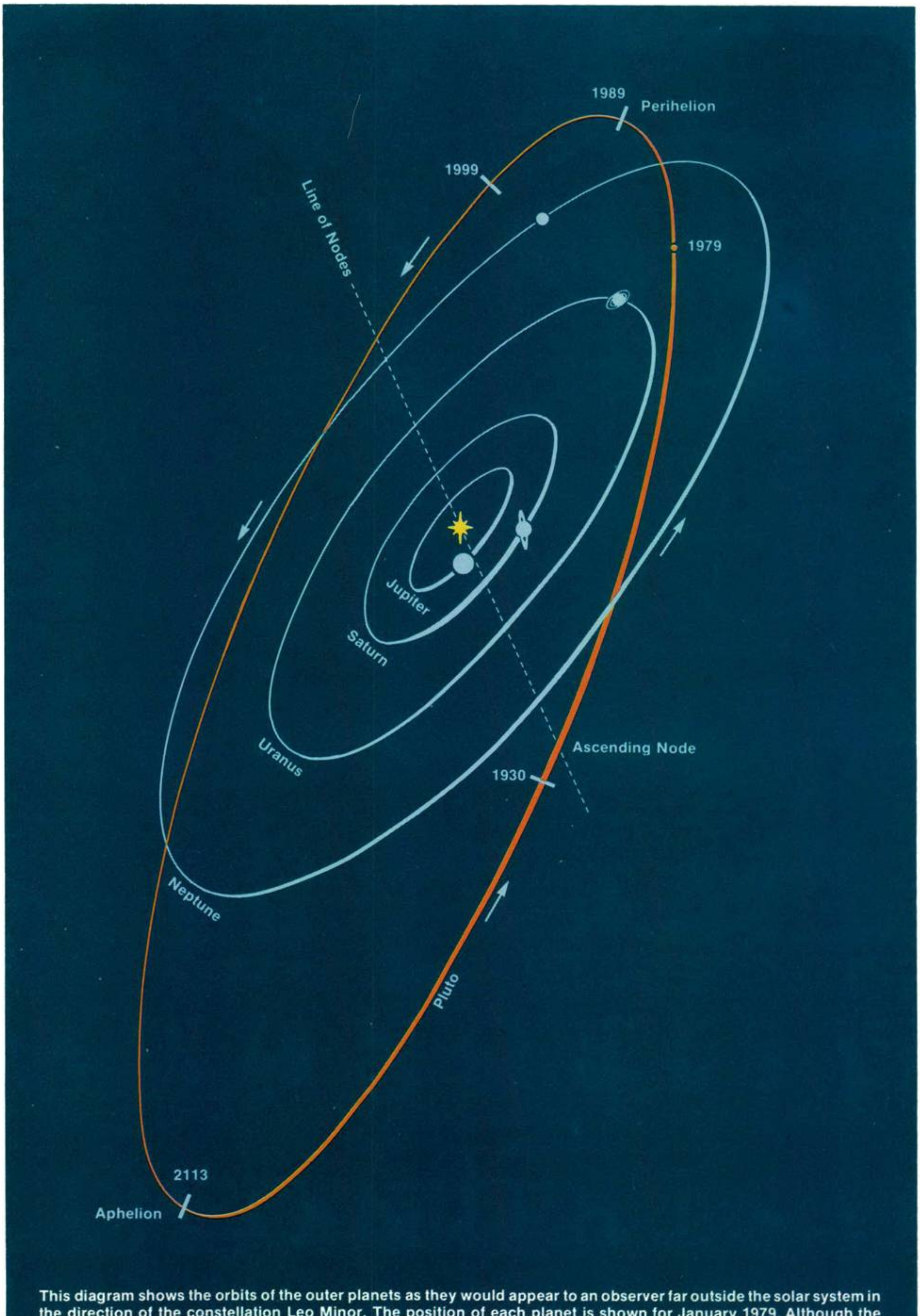
PLUTO:



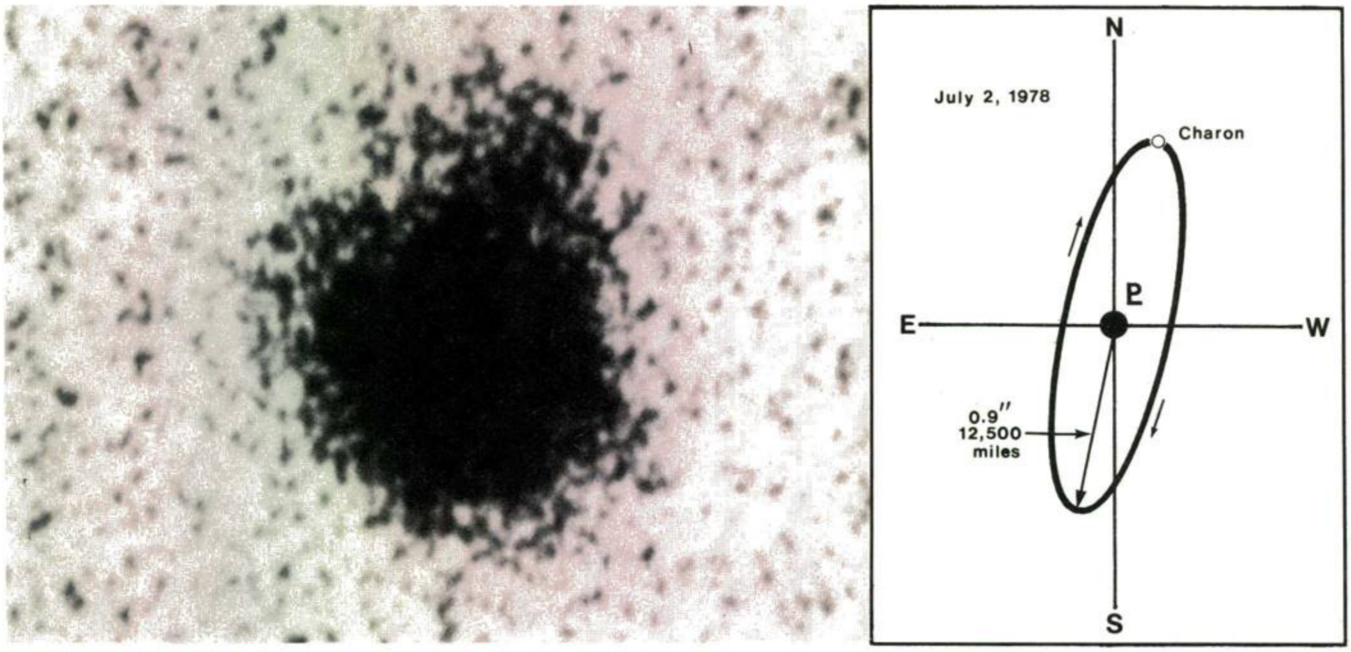
Pluto (left) and its newly discovered moon, Charon, are seen in this artist's conception of the image returned by a future space probe on a mission to the outer reaches of the solar system. Square picture elements, known as "pixels" to space scientists, have been computer processed to produce a close-up view of Pluto as an icy, irregular body. Charon, seen in the distance at upper right, also appears to be nonspherical. The actual shapes of Pluto and Charon are uncertain at present. Artwork by Anne Norcia.

Planet or Imposter?

by Ian Ridpath


1989
Perihelion
1999
Line of Nodes
1979
Jupiter
Saturn
Uranus
Neptune
Ascending Node
1930
Pluto
2113
Aphelion

This diagram shows the orbits of the outer planets as they would appear to an observer far outside the solar system in the direction of the constellation Leo Minor. The position of each planet is shown for January 1979. Although the orbits are shown to scale, the apparent size of each planet is greatly exaggerated! The inner orbits are too small to be shown — even that of Mars which is only 1/4 inch across on this scale. The dramatic irregularity of Pluto's orbit, more eccentric and inclined than that of any other planet, is obvious. From January 1979 until 1999, Pluto will be nearer to the sun than Neptune, although it is clear that Pluto cannot ever approach Neptune closely. Aphelion occurs in 2113, and Pluto will not return to the position where it was discovered in 1930 until 2178.



This photograph (above left) taken on July 2 with the U. S. Naval Observatory's 61 inch reflector at Flagstaff, Ariz., shows Pluto's satellite as a slight elongation of the image. The chart at right shows the true relative sizes of Pluto, Charon and Charon's orbit at the time of the photograph. The image is obviously blurred, demonstrating the difficulty of making accurate observations of Pluto! U. S. Naval Observatory photograph.

How many major planets are there in the solar system? Most people would say nine, which is the accepted number. Some might say ten, thinking that there could be another undiscovered planet at the outer edge of the solar system. But perhaps the real answer should be eight, for it is becoming increasingly clear that Pluto is not a true planet at all! Certainly, it is too small to have caused the supposed gravitational effects on the motions of Uranus and Neptune which led to its discovery!

To see what's behind the Pluto mystery, let's go back to the turn of the century when astronomers were speculating about the possibility of a ninth planet beyond Neptune. Neptune had been found in 1846 as a result of mathematical predictions based on irregularities in the motion of Uranus, which some astronomers realized could be due to the gravitational effect of an unknown body. But after the discovery of Neptune, it was found that Uranus (and Neptune as well) still didn't seem to be keeping to schedule. Was this because of the perturbing effect of yet another unknown planet?

Percival Lowell, of Mars fame, certainly thought so, and set about trying to predict the position of this unknown body. So, too, did William H. Pickering of Harvard, using a different method. But photographic searches in the predicted areas revealed nothing. Eventually, astronomers at Lowell Observatory in Arizona began an around-the-ecliptic search. Shortly after this search started, Pluto was discovered (in 1930) by Clyde Tombaugh, an observatory assistant hired for the job. He subsequently shot to fame and eventual success as a professor of astronomy.

But Pluto was a disappointing planet. Faint and evidently quite small, it was not the gas giant 6.7 times the mass of Earth that had been predicted by Lowell. Tombaugh continued his photographic search around the ecliptic, but no other planets were found, even though the search would have permitted discovery of Neptunelike planets up to about seven times Neptune's distance from the sun, or 200 astronomical units. Earthlike planets would have been found out to 100 astronomical units, according to Tombaugh.

Here was a paradox: Pluto was evidently not massive enough to have caused the perturbations that supposedly led to its discovery, yet there was no sign of a planet that could cause such perturbations. Most astronomers now believe the apparent irregularities in the orbits of the outer planets were unreal, caused mostly by observational errors and uncertainties in the orbits of Uranus and Neptune, and in star positions against which the planets' motions were measured. The discovery of Pluto seems to have been nothing more than a lucky fluke, a tribute to the thoroughness of the Lowell Observatory search rather than a vindication of any calculations.

To underline this conclusion, every time the size and mass of Pluto were measured, the planet seemed to get smaller and lighter. The best previous values suggested a diameter of 3,700 miles (5,900km) and a mass 0.11 that of Earth. There were two sources for the diameter estimate: visual observations by Gerard Kuiper with the 200 inch reflector in 1950, and a near occultation of a star by Pluto which placed an upper limit on its size. The mass estimate came from a study of the motion of Neptune, assuming it is still being slightly perturbed by the pull of Pluto.

What Is A Planet?

"A rose by any other name would smell as sweet." Of course Romeo was right: Words are words and things are things, and what we call them doesn't change their nature. But words do have meanings, and meanings — especially in science — are often quite important. Naming things is a way of classifying them, and proper classification is a first step in scientific study.

There are many objects in the solar system, and we have a number of names for them in order to divide them into classes based on similarities in nature and behavior. Among these categories are *comets*, *asteroids*, *satellites* and *planets*.

By the word planet, astronomers generally mean a nonluminous body (shining only by reflected light) of rather substantial size in a fairly regular orbit about a star. A satellite is a body in orbit about a similar body much larger in size. (For this reason many astronomers consider the Earth-moon system to be a double planet rather than a planet with a satellite, because Earth and the moon are closer in size than any other planet-satellite combination in the solar system — with the exception, now, of Pluto and Charon.)

But possession of a satellite is not necessarily an indication of planetary status. Mercury has no known satellites, and at least one asteroid — Herculina — appears to have a satellite. There are probably others.

Asteroids are planetlike bodies which are far too small to be considered planets; the very name asteroid means "starlike body" — one too small to show a discernible disk in a telescope. When the largest asteroid, Ceres, was discovered in 1801, it was thought to be a planet, especially since it was found to occupy the apparent gap between the orbits of Mars and Jupiter. But once its small size (diameter: 480 miles) became known and many other objects like it were found in the same region, it was obvious that Ceres did not rate the title planet.

Another property shared by planets seems to be a certain orbital regularity: All the planets (with the exception of Pluto) follow nearly circular orbits which lie in nearly the same plane (see the diagram on page 8). But Pluto's orbit is both rather eccentric (elongated) and inclined at 17 degrees to the orbital plane of Earth. And now, our latest discoveries about Pluto call its status as a planet even more into question.

"If you call a tail a leg, how many legs does a dog have?" Abraham Lincoln is said to have asked. "Five?" came the reply. "No, *four* — *calling* a tail a leg doesn't *make* it a leg!"

If you call Pluto a planet, how many planets does the sun have?

But new observations have meant that the accepted diameter and mass of the planet have had to be revised dramatically downward once again, as a result making Pluto the smallest and lightest planet in the solar system — even smaller than our own moon! The first part of the evidence concerns infrared observations published last year (reported in ASTRONOMY, February 1977) which show that Pluto's surface is brighter than has previously been estimated, and thus its size must be smaller than currently assumed, to account for its dimness. And, most importantly, a satellite of Pluto has recently been discovered (see Astro-News, September 1978) which allows the first accurate calculation of its mass.

The satellite was discovered by astronomer James Christy of the U.S. Naval Observatory on photographs taken with the 61 inch reflector at the observatory's outstation at Flagstaff, Ariz., as part of a program to refine knowledge of Pluto's 248 year orbit. Christy noted an elongation of Pluto's image, which was also visible on photographs taken at the observatory in 1965 and 1970, but which had previously been dismissed as faults in the photographic emulsion. A confirming plate taken with the 158 inch reflector at Cerro Tololo Inter-American Observatory in Chile also showed the elongation.

There seemed no plausible explanation of the elongation other than that it's caused by a satellite orbiting close to Pluto, so in July 1978, discovery of a moon of Pluto was announced. It is officially termed 1978-P-1, but discoverer Christy named it Charon, after the mythological boatman who ferried souls into the underworld, of which Pluto was god.

According to Dr. Robert S. Harrington of the U.S. Naval Observatory, the satellite orbits at about 10,500 miles from the center of Pluto every 6.4 days, which is the same time as the planet spins on its axis. Therefore, Charon must hang over one point on Pluto like a geosynchronous satellite does over a point on Earth.

Charon's diameter is estimated from its brightness to be 40 percent that of Pluto, making it larger in proportion to its parent planet than any other moon in the solar system. But most important of all, a study of its orbit has allowed Harrington to calculate an accurate mass for Pluto: 0.002 that of Earth, or 40 times lighter than currently estimated! Combined with a diameter of 1,500 miles measured by the infrared observations, Pluto appears to have a density slightly more than that of water. Therefore it can be nothing more than a low density snowball of frozen gases. This is consistent with the infrared observations which *did* detect plentiful methane frost on its surface.

Several of Saturn's satellites are believed to have low densities similar to Charon's. The similarity of Pluto to the satellites of the outer planets has seemed to add some weight to the supposition that Pluto is an escaped moon of Neptune. This theory, first proposed by Prof. Raymond Lyttleton of Cambridge University, supposes that Pluto once orbited Neptune every 6.4 days, until it suffered a close encounter with another moon, Triton. During this event, Triton was thrown into its current retrograde orbit while Pluto was ejected to pursue its own course as an independent planet. (As a matter of interest, the latest diameter estimates of Triton suggest it is twice the size now measured for Pluto.) But how can we account for Pluto's own moon with this theory?

Pluto Facts

This table shows the dramatic changes in our knowledge about Pluto which have taken place in recent years. Estimates of its mass and diameter have declined sharply, while much that was unknown has now been learned. Not so long ago the great mystery of Pluto was its seemingly high density, but we now know that its density is in reality much less than that of Earth. Together with the new low figures for its size and mass, this raises the question of whether Pluto has any right to the title "planet" at all!

	1960	1975	1978
Diameter (miles)	3,700	3,700	1,500
Mass (Earth = 1)	0.7(?)	0.11	0.002
Density (grams/cubic centimeter; water = 1)	36.8	5.75	1.5
Density (Earth = 1)	6.66(?!)	1.04	0.27
Period of rotation	?	6.39^d	6.39^d
Inclination of equatorial plane to plane of orbit	?	?	57°
Effective surface temperature	-230°C.	-230°C.	-230°C.
Atmosphere	?	?	none
Satellites	0	0	1
Orbital period of satellite	---	---	6.39^d

No satellite of the solar system is known to have a moon of its own, although there is suspicion that some asteroids may have companion bodies.

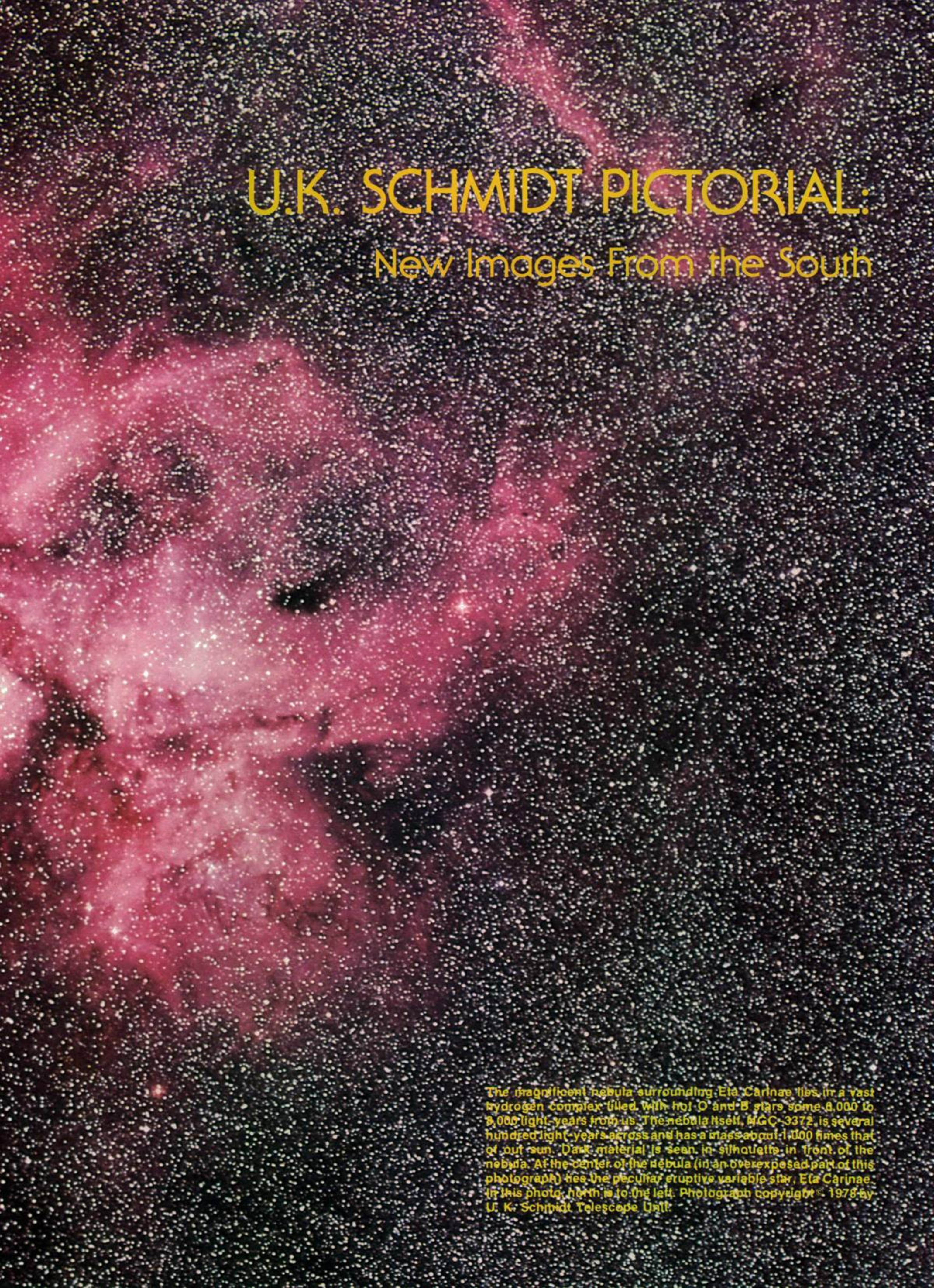
A new theory being advanced by Thomas Van Flandern of the U. S. Naval Observatory and Harrington supposes that Pluto is a former satellite of Neptune. When a hypothetical planet nearly collided with Neptune long ago, its satellite system was disrupted, and Pluto was ejected. During the encounter, tidal forces ripped a chunk off Pluto, which continues to orbit as the moon. The intruder planet was itself highly perturbed by the encounter and was thrown into an orbit far from the sun. The theory supposes it now orbits there, too faint to be seen. Thus, Harrington and Van Flandern have revived the prospect of a 10th planet, but for a different reason than to account for the motions of Uranus and Neptune.

They propose that this extra planet (if it exists) has a mass three or four times that of Earth and orbits 50 to 100 astronomical units from the sun. Some years ago, American astronomer Dennis Rawlins and the Englishman Max Hammerton calculated from the motion of Neptune that such a body might exist in the direction of the constellations Capricornus, Aquarius or Pisces. Perhaps, they suggested, it was missed in the Lowell search. If a new search in these areas reveals nothing, then the last hope of a major planet existing beyond Pluto will have evaporated.

But should Pluto itself be regarded as a major planet? For one thing, its orbit crosses that of another planet, which no other major planet does. From Jan. 22, 1979 until March 1999, Pluto will come closer to the sun than Neptune, meaning that the solar system temporarily has a "new" outermost planet. Pluto's orbit is in fact reminiscent of Chiron, the minor planet discovered last year by Charles Kowal at Mt. Palomar (see Astro-News, February 1978), which itself was hailed as the 10th planet before its true diminutive nature became clear. Chiron spends most of its time out beyond Saturn (where it is now), but for part of its orbit it crosses Saturn's path to come closer to the sun. Chiron seems to be an icy, low density body similar in nature to the outer moons of Saturn. Does this description sound familiar?

Although Chiron is only 100 miles or so across, which is 1/10 the size of Pluto, both Chiron and Pluto may well be examples of the building blocks of the outer planets which were never swept up. Phoebe, the outermost satellite of Saturn, has properties so similar that Phoebe seems almost a twin of Chiron that was captured to become a moon. Is it possible that, instead of being a moon of Neptune that escaped, Pluto is a potential moon that was never captured? And should it, like Chiron, be classified as a minor planet or asteroid?

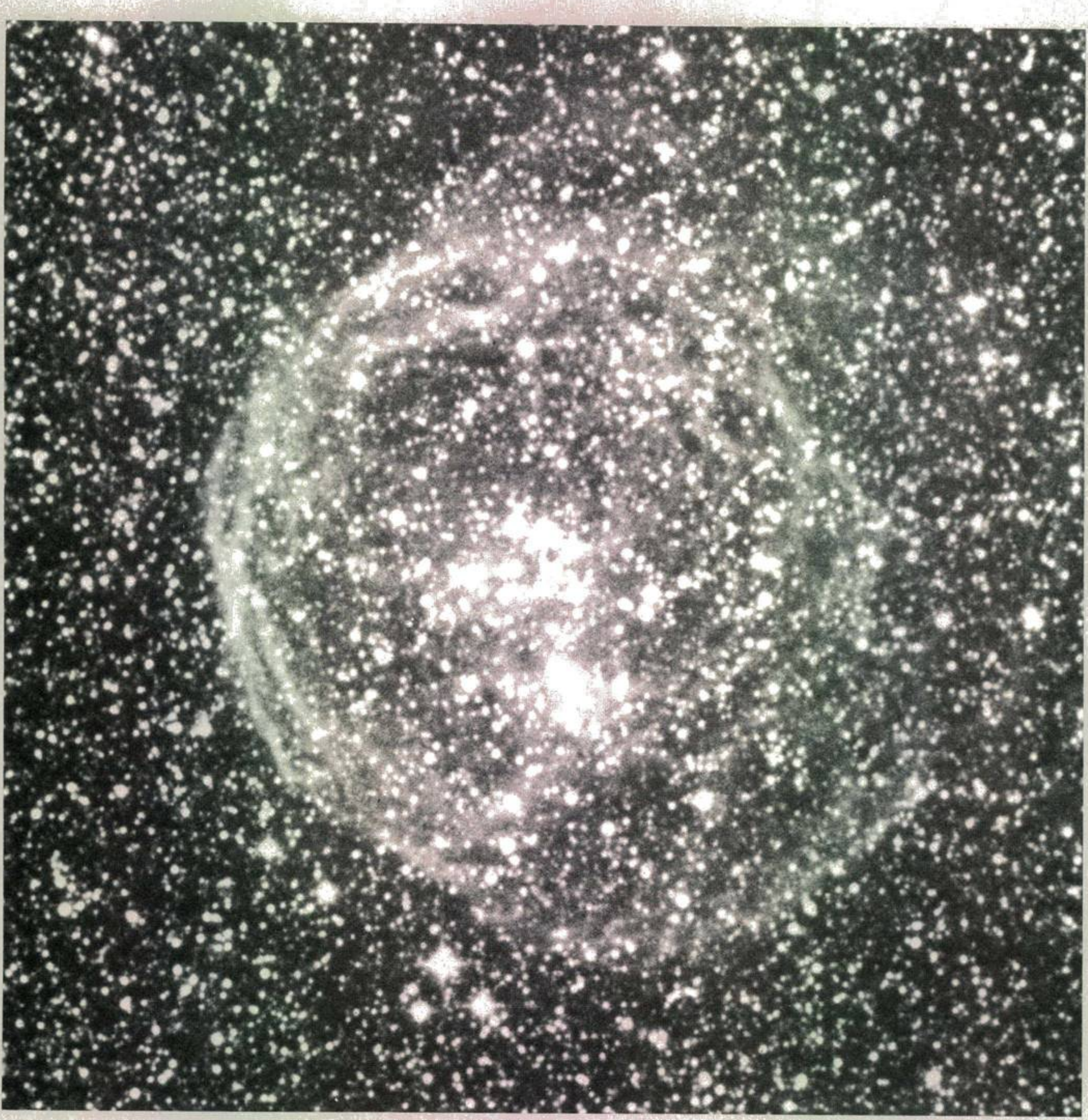
As Pluto moves toward perihelion in 1989, astronomers will give increasingly close scrutiny to this controversial — and probably overrated — member of the solar system.



U.K. SCHMIDT PICTORIAL:

New Images From the South

The magnificent nebula surrounding Eta Carinae lies in a vast hydrogen complex filled with hot O and B stars some 6,000 to 8,000 light-years from us. The nebula itself, NGC 3372, is several hundred light-years across and has a mass about 1,000 times that of our sun. Dark material is seen in silhouette in front of the nebula. At the center of the nebula (in an overexposed part of this photograph) lies the peculiar eruptive variable star, Eta Carinae. In this photo, north is to the left. Photograph copyright © 1978 by U. K. Schmidt Telescope Unit.

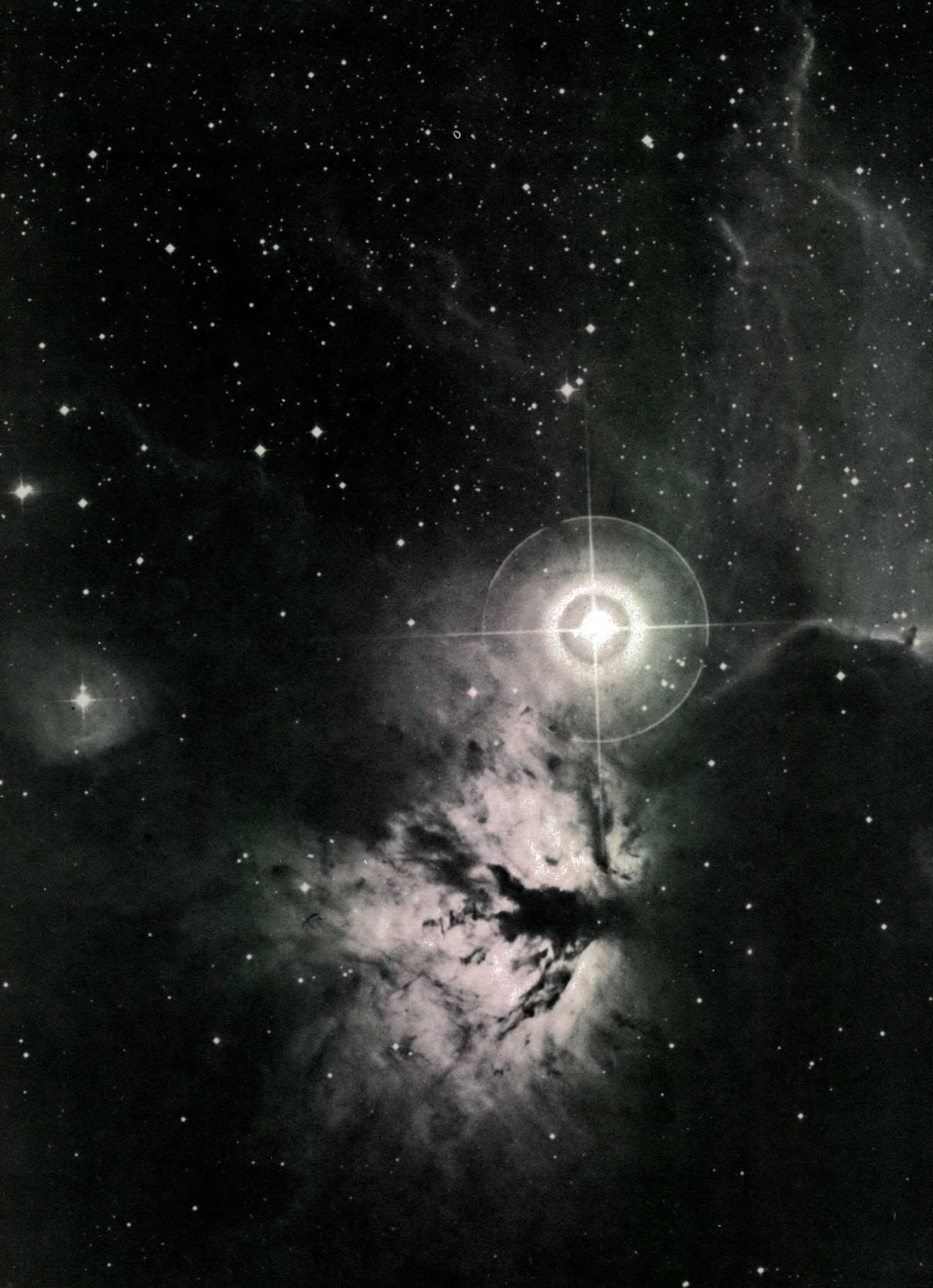


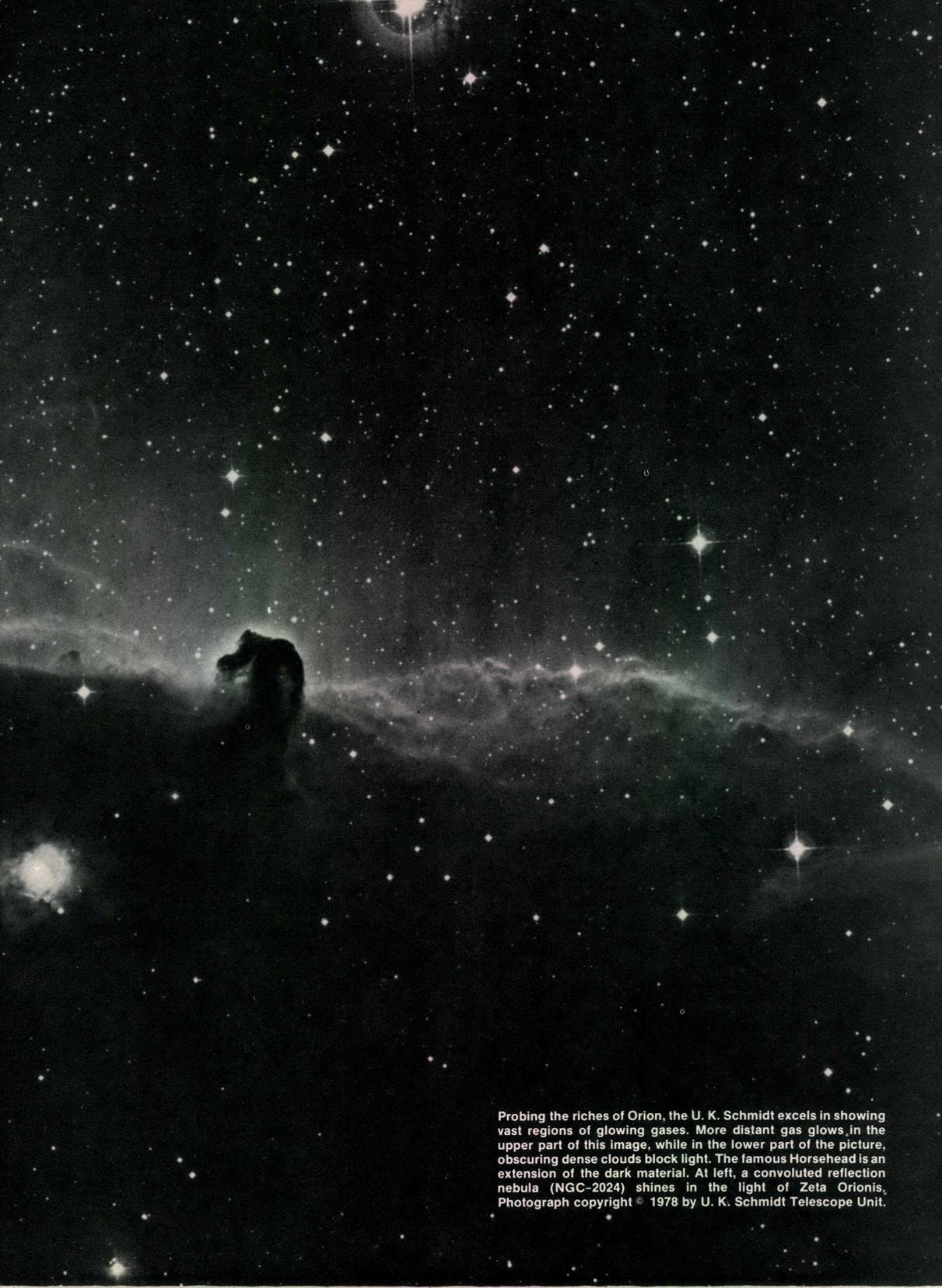
Left: Embedded in a dazzling field of stars, the Lagoon (below) and Trifid (above) suggest the ability of the U. K. Schmidt to cover broad reaches of sky — nearly a two degree span here. The full field is more than three times greater in height and four times greater in width! Above: Moving in for the close-up is another of the U. K. Schmidt's abilities. This supernova remnant lies in the Large Magellanic Cloud, 160,000 light-years distant. Photographs copyright © 1978 by U. K. Schmidt Telescope Unit.

"The world's most powerful astronomical camera" began photographing southern skies a little over five years ago. What instrument was it? Well, it wasn't a new giant telescope; it was the 48 inch (1.2m) Schmidt telescope operated in Australia by the British Science Research Council. Known as the U.K. Schmidt, the instrument is located far from artificial lights and smog on Siding Spring Mountain, near Coonabarabran, New South Wales.

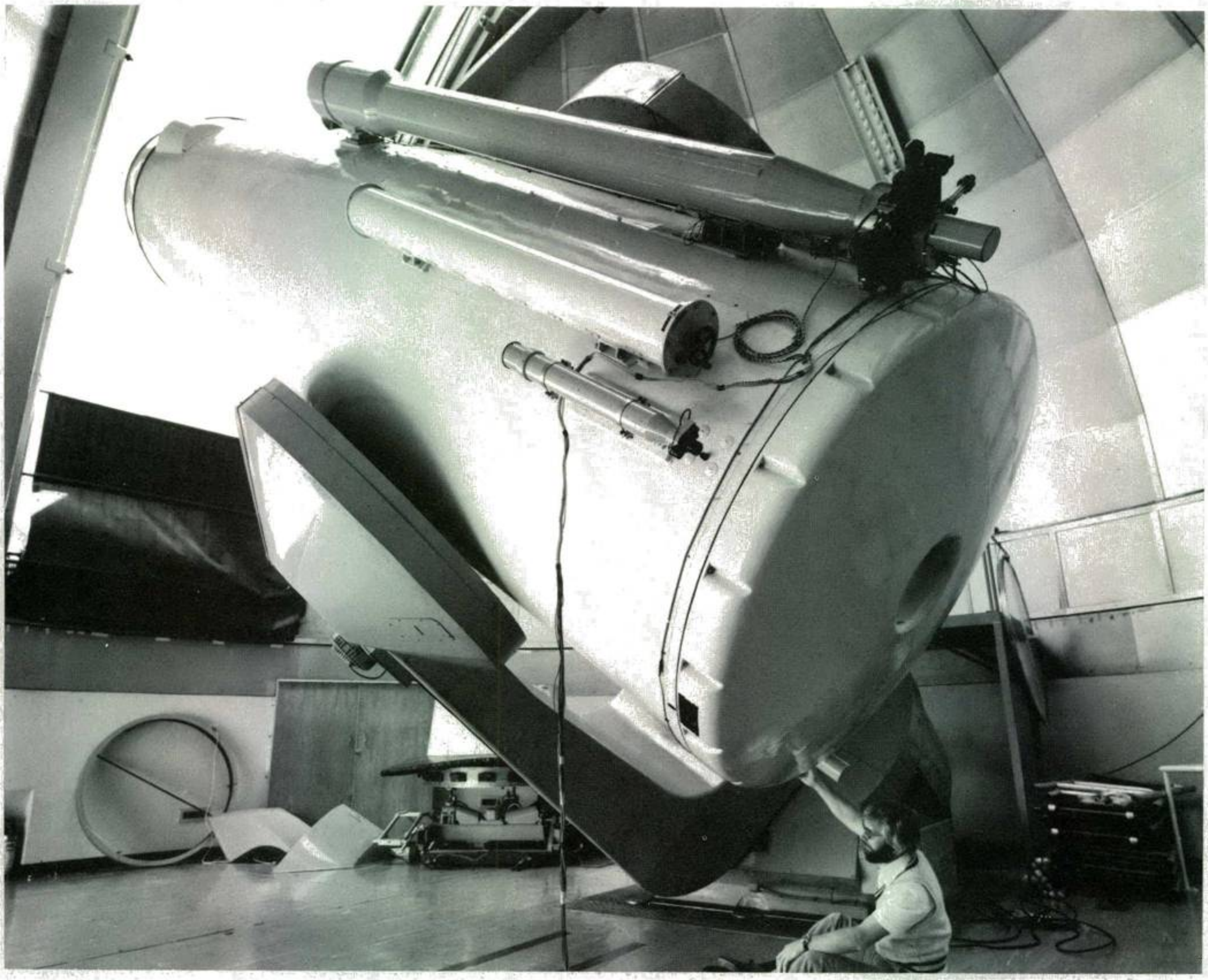
The claim that it's the world's "most powerful" astronomical camera isn't just talk either. Though the biggest telescopes in the southern hemisphere (the 4 meter Cerro Tololo and 3.9 meter Anglo-Australian telescopes) can record objects somewhat fainter, the sheer speed and precision of the Schmidt put it far ahead in terms of recording huge numbers of astronomical objects. For example, it would take 40 photographs with the 3.9 meter Anglo-Australian telescope to record as much sky as the 1.2 meter U.K. Schmidt can in one exposure — and the Schmidt exposure would only take half as long.

Astronomers planned it that way, of course, because the Schmidt was partly intended to serve as a "finder" for the big southern telescopes, just as the 48 inch Schmidt on Mount Palomar serves as a





Probing the riches of Orion, the U. K. Schmidt excels in showing vast regions of glowing gases. More distant gas glows in the upper part of this image, while in the lower part of the picture, obscuring dense clouds block light. The famous Horsehead is an extension of the dark material. At left, a convoluted reflection nebula (NGC-2024) shines in the light of Zeta Orionis. Photograph copyright © 1978 by U. K. Schmidt Telescope Unit.



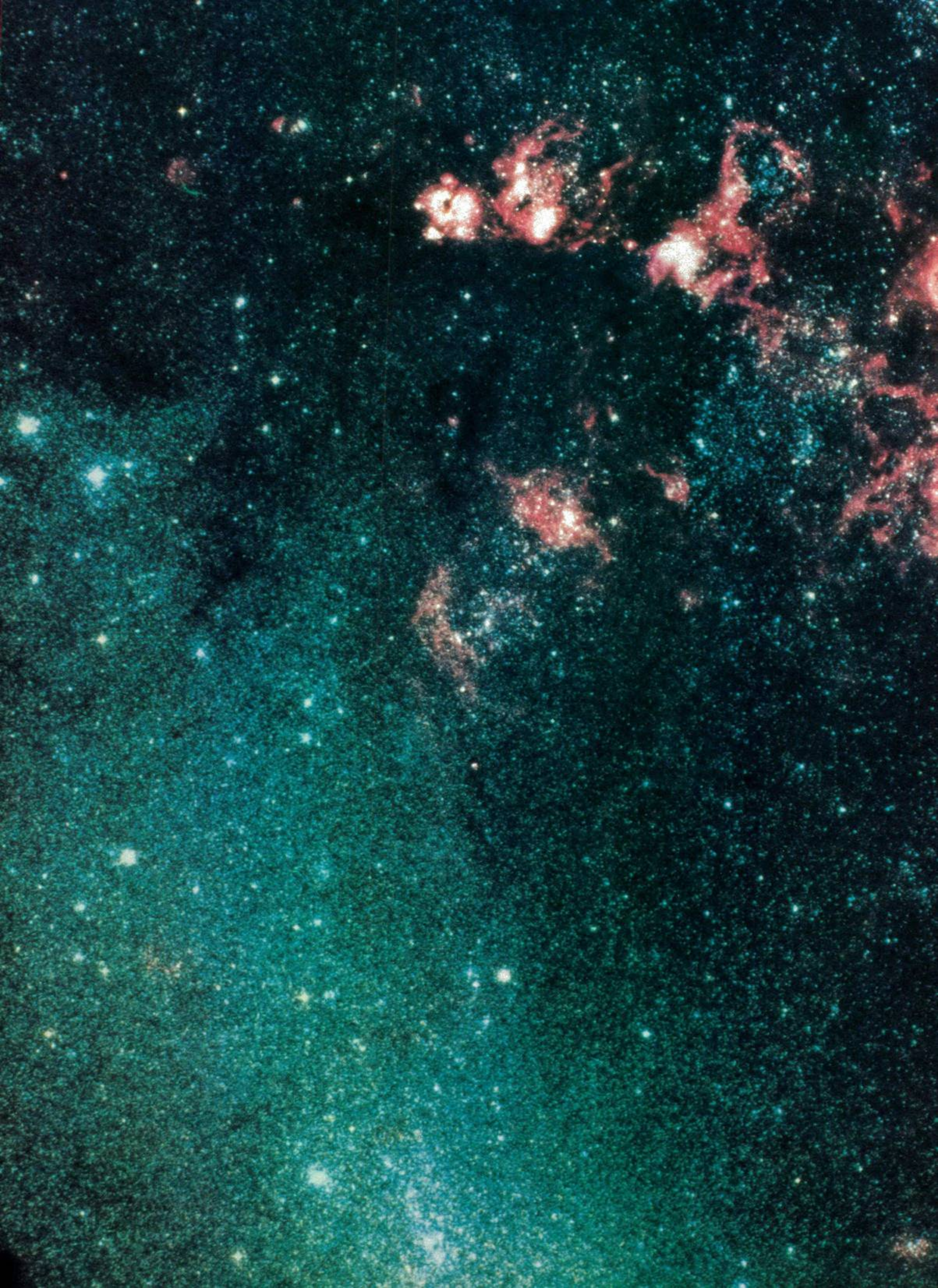
"finder" for the 200 inch Hale telescope. But its first task is to photograph all the southern sky that the famous National Geographic Society-Palomar Observatory Sky Survey could not reach. For 20 years this photographic atlas has been invaluable to astronomers, and a survey of the southern hemisphere skies was long overdue. The U.K. Schmidt began regular work in 1973, and now approximately 75 percent of the 606 exposures for the atlas have been completed.

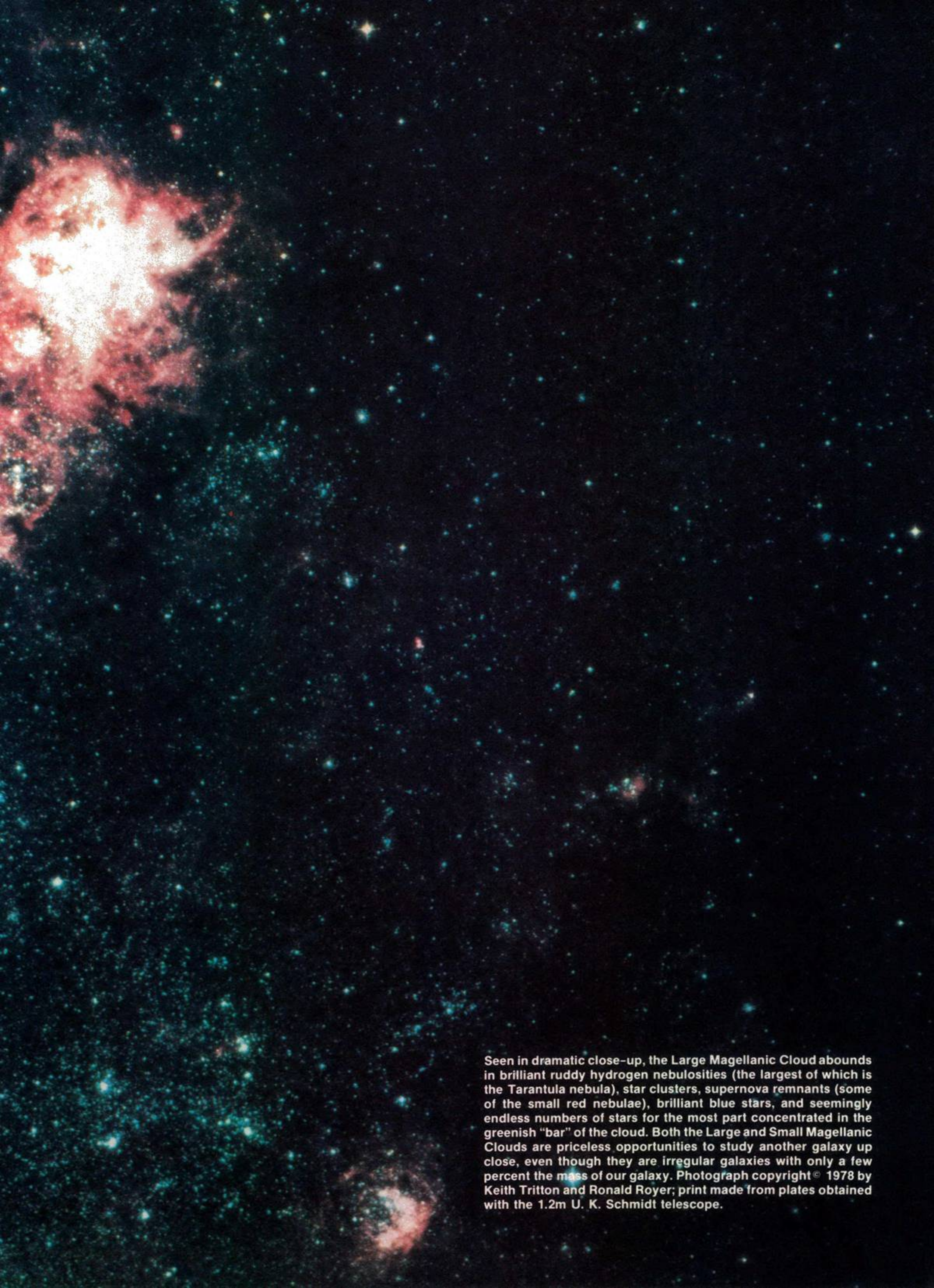
But it turns out that the U.K. Schmidt southern sky atlas will be much better than the Palomar atlas: The plates record much fainter objects, so in effect, the U.K. Schmidt penetrates so much deeper into the universe. Why? In the 20 years since the Palomar survey, there have been major improvements in both photographic and telescope design. And astronomers from Palomar were able to help too, pointing the way to many significant improvements.

Most important, perhaps, is the improvement in photographic emulsions. While "fast" films are one answer to the problem of recording faint astronomical objects, they are limited by their coarse grain. And they aren't very efficient in their handling of light either: At best, only about one percent of the photons reaching the plate get converted into a useful image. Kodak researchers invented a more efficient kind of emulsion — fine grained, high contrast and rather slow. Type IIIa-J, as it's called, may be as efficient as four percent — four times better than the old emulsions! In addition, the low graininess means the pictures can be enlarged much more, and they're sharper too. The availability of these improved emulsions had a major impact on the design of the U.K. Schmidt.

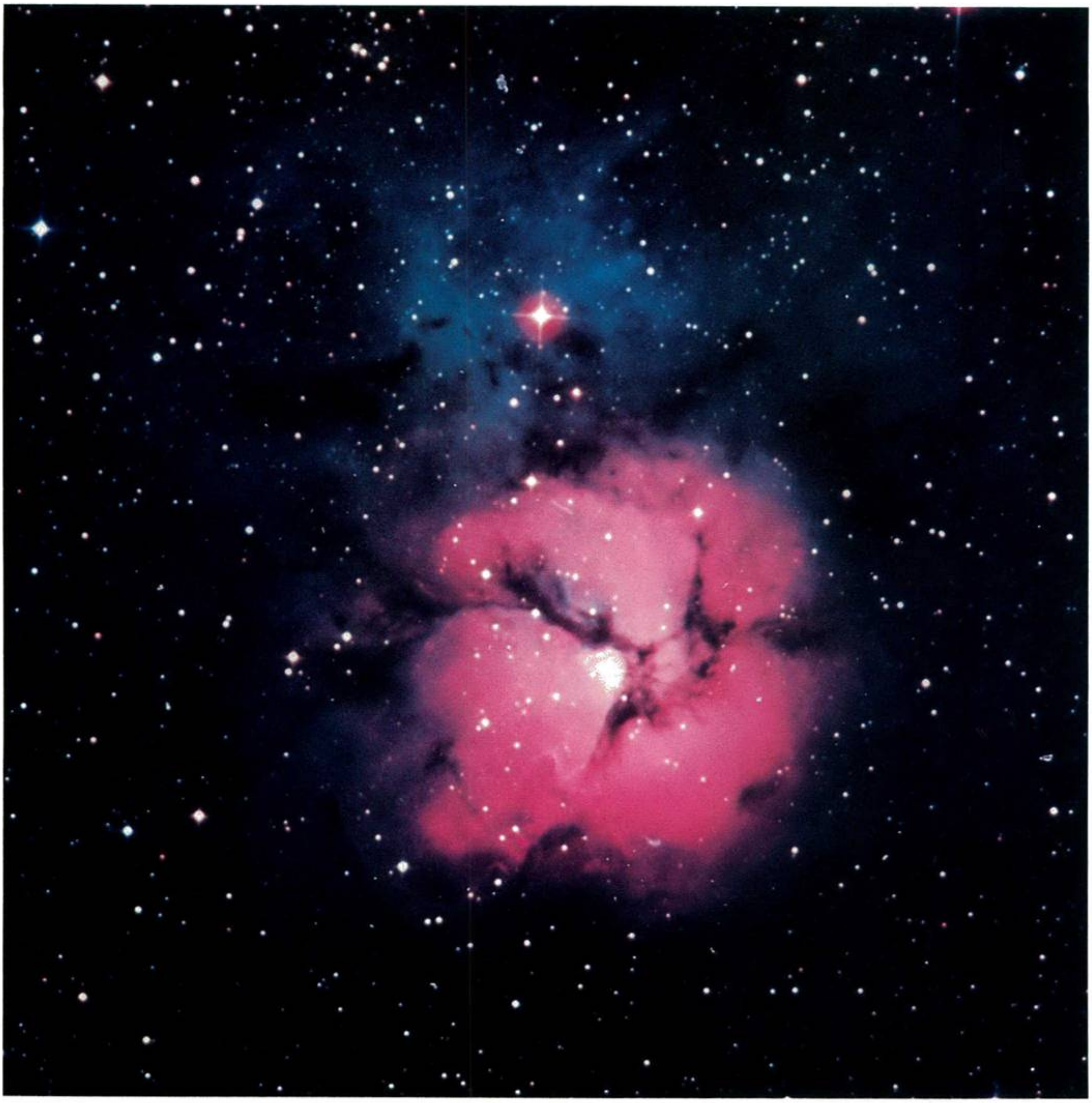
Above: The "world's most powerful astronomical camera" looks a lot like the Palomar Schmidt, but tighter specifications and 25 years of progress in telescope design lie between them. The U. K. Schmidt's success depends to a large degree on improved photographic emulsions and automatic guiding. Right: The spiral galaxy NGC-6744 is an open spiral with a small bar in the center, and is one of the few nearby galaxies *not* associated with a group of other galaxies. Photographs copyright © 1976 by U. K. Schmidt Telescope Unit.

The 48 inch Palomar Schmidt isn't perfectly sharp — it's good, but not perfect. In blue light, its images are .001 inch pinpoints, but in red or ultraviolet light they're nearly twice as big. With the old grainy emulsions it didn't matter, but with the new fine grain emulsions, images had to be





Seen in dramatic close-up, the Large Magellanic Cloud abounds in brilliant ruddy hydrogen nebulosities (the largest of which is the Tarantula nebula), star clusters, supernova remnants (some of the small red nebulae), brilliant blue stars, and seemingly endless numbers of stars for the most part concentrated in the greenish "bar" of the cloud. Both the Large and Small Magellanic Clouds are priceless opportunities to study another galaxy up close, even though they are irregular galaxies with only a few percent the mass of our galaxy. Photograph copyright © 1978 by Keith Tritton and Ronald Royer; print made from plates obtained with the 1.2m U. K. Schmidt telescope.



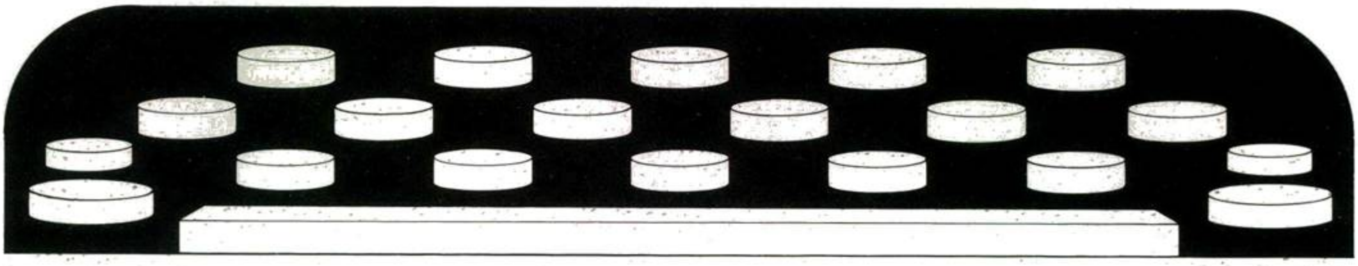
The Trifid nebula (also shown in the photograph on page 14) shows a striking contrast in color because it consists of two types of nebulae: The red part glows from hydrogen excited by stars inside, and the blue part is a reflection nebula consisting of interstellar material that is simply illuminated by a star. Overlying the whole region is dark nebulosity, blocking light from the glowing areas. Photograph copyright © 1978 by U. K. Schmidt Telescope Unit.

better. So did the tracking, mechanical stability, guiding and every other part of the design that might cause fuzzy pictures.

In order to improve image sharpness, astronomers designed an achromatic Schmidt corrector. The images it produces as part of the U.K. Schmidt are not only much smaller and sharper than those of the 48 inch Palomar Schmidt, but because it's achromatic, it also works well in ultraviolet and infrared light.

To improve guiding and tracking, the mechanical specifications of the U.K. Schmidt were made much tighter. In addition, the telescope has an automatic guiding system. This means the body heat of an observer guiding a star image is no longer a disturbing influence: The observer is comfortably seated in a warm insulated room. Meanwhile, the telescope gives noticeably better images!

After the present survey (which is being done in blue/green light), astronomers hope to do two more surveys — one in red hydrogen alpha light, and the other in the near infrared part of the spectrum. The infrared survey will be especially valuable to astronomers working on plans for the Infrared Astronomy Satellite (IRAS) planned for the early 1980s.



IN FOCUS

Sir / In "What's Inside Your Telescope, Part 1" (March 1978), Robert Cox states that telescope lenses are not cemented together because the difference in thermal expansion would cause image distortion. Why, then, are the achromatic lenses in many oculars cemented? Doesn't this cause trouble?

MIKE BELL
New Providence, N.J.

Mr. Bell / No, it doesn't. Over the diameter of a lens as small as a typical eyepiece lens, the strains caused by differences in thermal expansion are not important. Objective lenses, in fact, often are cemented in binoculars and riflescopes where the lens diameter is less than three or four inches.

In one case, however, cemented eyepiece lenses can cause trouble — and that's when you are projecting the image of the sun with a telescope. Because lenses may get fairly hot, differential expansion and possibly burning of the cement can damage the eyepiece. For solar image projection, especially with telescopes larger than four to five inches, it's a good idea to use Ramsden or Huygens eyepieces that have no cemented lenses.

Sir / I am seeking information regarding the origins of constellations. Would you have any material on these topics or could you suggest where I might pursue the subject?

JAMES GREENWALD
Milwaukee, Wisc.

Mr. Greenwald / We suggest you examine a copy of Richard H. Allen's **Star Names: Their Lore and Meaning**, *published by Dover Press in paperback. In addition to what the title says, Allen explains pre-Greek and Asian celestial mythologies concerning stars, constellations, the ecliptic, etc. We'll sell you a copy for $5.50 postpaid.*

Sir / I am compiling a computer card index of data on the nearer stars — right ascension, declination, distance, etc. As much data as possible is desired, but local literature is usually outdated. I'm talking about comprehensive data on the 1,000 nearest stars — something it would take a computer to sift through.

I think the **Near Star Catalog** is what I need. I just heard of it recently, but the title alone suggests that it might fit my requirements. Do you know if it's a good source and where I might get a copy?

MICHAEL BONNES
Brookings, S.D.

Mr. Bonnes / The catalog you speak of is the **Catalogue of Nearby Stars** *by Wilhelm Gliese. It's number 22 in the Veröffentlichungen ("Contributions") series of the Astronomisches Rechen-Institut, Heidelberg, West Germany. Many professional observatory libraries will have a copy, as may some university libraries. The catalog was published in 1969 and may now be out of print at the Rechen-Institut. Their address is: Astronomisches Rechen-Institut, Mönchhofstrasse 12-14, 69 Heidelberg, West Germany.*

Sir / The object near Theta, Rho, and Sigma Andromedae on the enclosed photograph, which I took in November 1975, does *not* appear on your photo of the same region (October 1978, page 46). What could it be? What happened to it?

R. L. QUINLIVAN
St. Louis, Mo.

Mr. Quinlivan / By luck, you caught a long period variable star near its maximum! The Skalnate Pleso **Atlas of the Heavens** *shows a variable star at this position, R Andromedae. The* **General Catalog of Variable Stars** *identifies this as a Mira Ceti type variable, which is a long period giant variable. It has a minimum magnitude of 14.9, a maximum of 6.0, and a period of 408.97 days. Your photograph shows it at about seventh magnitude, about a month after its maximum. For those who wish to look for this variable, the next maximum will occur about the middle of February 1979.*

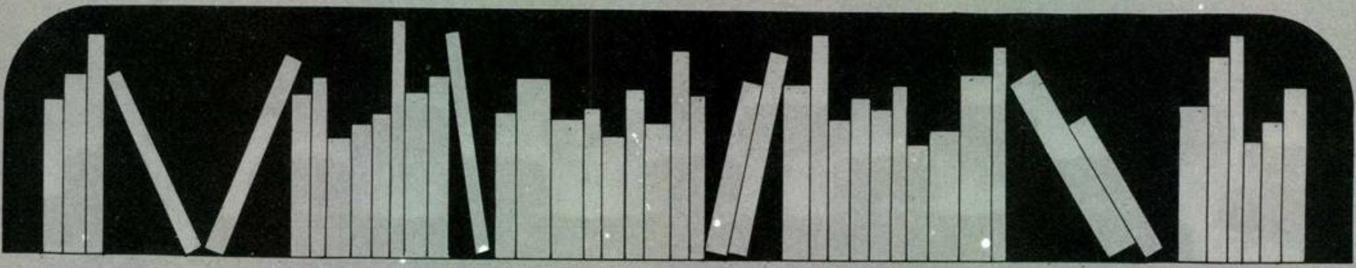
Sir / I've been considering the purchase of several star catalogs, but am hampered, however, not only by monetary restrictions but by not knowing what catalogs are available, from whom and what they contain. Can you give me a short list of major star catalogs, what they contain and where they may be purchased?

JONATHAN EDWARDS
Lexington, Ky.

Mr. Edwards / There are three star catalogs in common use today: the Yale **Catalogue of Bright Stars**, *the* **Atlas of the Heavens-II Catalogue**, *and the* **SAO Star Catalog**. *The first of these has information on positions, brightnesses (V and B-V), spectral classes, parallax, radial velocity, proper motions, and notes on double stars (where applicable) of 9,100 stars in both celestial hemispheres. It sells for around $15. The second catalog lists much the same information, except there's no B-V brightness value. The catalog also contains tables for converting parallax into distance, magnitudes into brightness differences, etc. It accompanies the Atlas of the Heavens. covers the whole sky, and sells for abou*

The th [illegible] talog is prepared by the Smithsonian Astrophysical Observatory for tracking satellites. It is primarily a positional catalog: Positions are given for over 250,000 stars (both celestial hemispheres), along with their annual changes due to precession and proper motion. The data on brightnesses and spectral classes are rudimentary, for they were ancillary to the catalog's intent. It's a U.S. government publication (#047-000-00006-8), and the four volume set sells for $35.70.

Try writing to one of the following dealers, and ask for a list and prices: Herbert A. Luft, P.O. Box 91, Dept. A, Oakland Gardens, N.Y. 11364; Willmann-Bell Inc., P.O. Box 3125, Dept. A, Richmond, Va. 23235; The Astronomical Unit, 3704 John F. Kennedy Blvd., Dept. A, North Little Rock, Ark. 72116.



ASTRONOMY REVIEWS

Extraterrestrial Intelligence: The First Encounter
edited by JAMES L. CHRISTIAN

303 pages (illus.), hardcover, $13.95
Prometheus Books (1976)

Any day now, radio astronomers may detect signals from an extraterrestrial civilization. NASA, in fact, has requested $2.1 million for fiscal 1979 to begin the most thorough search to date. Cornell University astronomer Frank Drake believes that NASA's program, continued to the year 2000, would have a 50 percent chance of success.

Few astronomers are so optimistic, but most consider communication with extraterrestrial intelligence (CETI) a serious possibility. Discussion of CETI, however, usually focuses on techniques of contact; scant attention has been given to what might happen *after* we receive a message. That's why this collection of 15 essays is must reading for anyone concerned about the human impact of CETI.

"This book is a philosophic enterprise", explains Christian in the preface. "It is speculative." The contributors, mostly philosophers and scientists, assume that life pervades the universe. They agree that CETI will spark an intellectual and cultural upheaval rivaling the revolutions of Copernicus and Darwin. Several go on to explore the possible religious, social and philosophic repercussions of our first encounter.

Possibly to boost the book's sales appeal, Christian has recruited some "big name" contributors. Science fiction great Ray Bradbury opens the volume with an energetic celebration of the philosophic spirit. The prolific Isaac Asimov provides an able if uninspired history of man's speculations about life on other worlds. Leonard Nimoy, alias Mr. Spock, recounts what it was like to play an "alien" on television.

Don't be fooled. Here, at least, the writers with the most to say are the least well-known. Christian, for example, maintains that CETI will shake humanity to its roots by proving we are "little more than toddlers in the cosmic kindergarten". Several contributors suspect that CETI will create a "new species" of man that transcends our all-too-human hang-ups and limitations. Contact with aliens who enjoy unique psychobiological ways of knowing or feeling, for instance, might vastly expand human vistas, psychologist Joseph Royce suggests.

Christianity learned to live with Copernicus and Darwin, so it may survive CETI, too, says theologian William Hamilton in a 1989 "CBS News Special". Religious leaders will emphasize that God created both heaven and Earth, so alien life poses no threat to the faith, Hamilton predicts. Philosopher Ronald Huntington thinks that Eastern religions might take CETI with aplomb. Hindus and Buddhists, after all, have long believed that blue skinned, four armed avatars and other strange beings inhabit distant worlds. In fact, Indians eagerly await contact with such creatures who, they expect, will lead humanity to a higher consciousness.

Many contributors wonder how we will react if extraterrestrials tell us that immortality is a technological achievement rather than a religious conviction. Speaking through a short story about a "cosmic caddis fly", philosopher Herman Tennessen warns that immortality might challenge the human meanings of life. Do we try to compensate for our brief time on Earth by seeing life as a means to some end, such as happiness or heaven, Tennessen asks?

In the most telling essay of the bunch, science newsman Kendrick Frazier reminds his colleagues that the tone of the first reports about CETI could strongly color the way the world perceives the event. Accurate stories will head off groundless fears about flying saucer invasions, Frazier notes. Astronomers must also strive to keep the public fully informed.

Always provocative, these speculative pieces are sometimes hard reading. Occasionally they get off on the wrong philosophic foot. Thus, one philosopher, wondering how we ought to behave toward aliens, grapples for 16 pages with the question: "Would ETIs Be Persons?" (Yes, he in effect concludes, if they are self-conscious and love life.) But the word "person" usually means "human being", so the very question implies a terrestrial bias. To clearly see our moral obligations in a universe of ETIs, we probably need a new definition of man.

The volume ends with a unique collection of nearly 200 questions to provoke further thought about the impact of CETI on our species. As **Extraterrestrial Intelligence** makes clear, it's high time scientists, humanists — all of us — begin to seriously think about the consequences of contact and even plan for them. *Michael Thacher.*

NEW ASTRO-BOOKS

Man and the Stars
by HANBURY BROWN

185 pages (illus.), hardcover, $14.95
Oxford University Press (1978)

The author, an astronomer at the University of Sydney, Australia, has written a lucid nontechnical account of the relevance and importance of astronomy to human culture.

The Road to the Stars
by IAIN NICOLSON

224 pages (illus.), hardcover, $14.95
William Morrow (1978)

This nontechnical book reviews "current and predictable technologies for use as the human race expands through the galaxy". The author is a British science writer and journalist.

Stars and Nebulas
by W. J. KAUFMANN

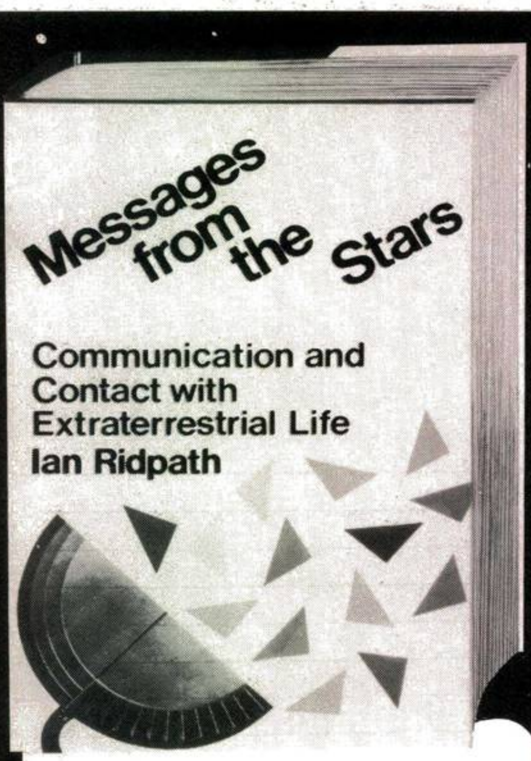
204 pages (illus.), paperback, $7.00
W. H. Freeman (1978)

This book is the first of a trilogy explaining developments in modern astronomy for a nonspecialist audience.

Astronomy
by D. L. MOCHE

282 pages, paperback, $5.95
John Wiley (1978)

The author has prepared a self-teaching book designed to help those working on their own to learn about astronomy. Many examples and simple experiments are given along with the programmed text.


Messages from the Stars
Communication and Contact with Extraterrestrial Life
Ian Ridpath

The next voice we hear may be theirs.

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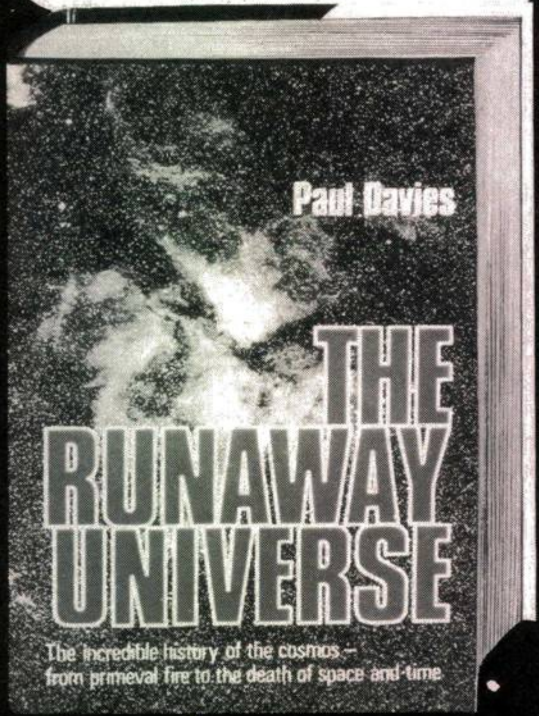
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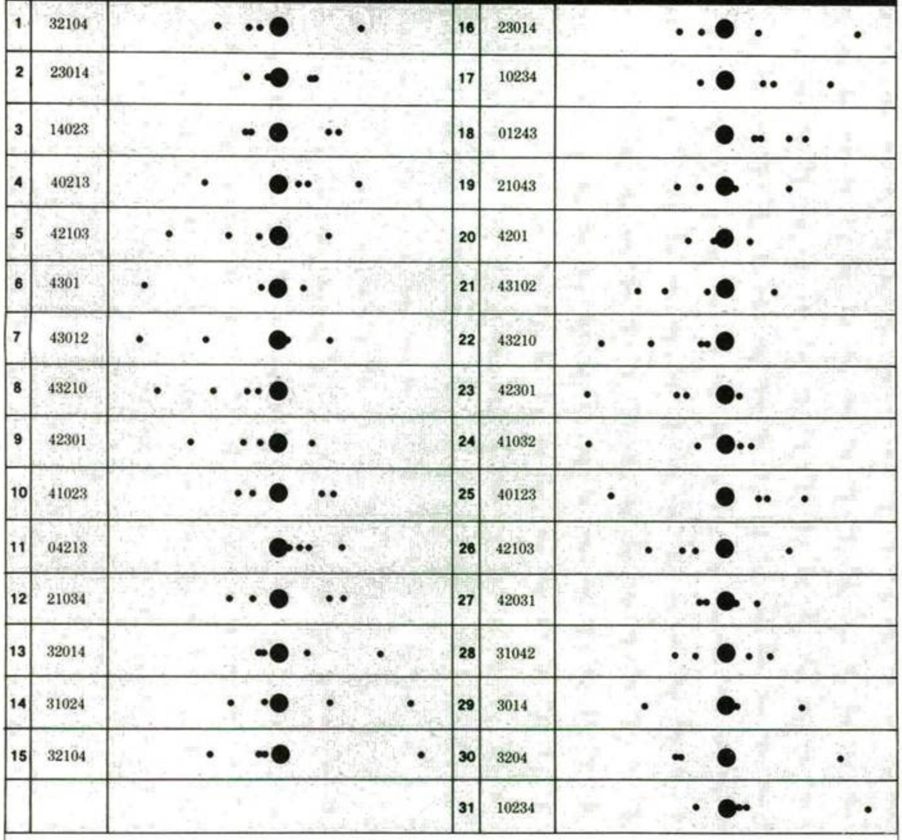
SKY ALMANAC

A Grand Occultation of Venus!

December Satellites of Jupiter 09:00 UT, 04:00 EST, 01:00 PST



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The four major satellites of Jupiter orbit the planet in periods ranging less than 2 days to 17 days. You'll see them change position from night to night. This table shows the approximate position of the moons each night. The column at the far left shows the date; the second column gives the names of the moons (Jupiter = 0, Io = I, Europa = 2, Ganymede = 3, Callisto = 4). The third column shows the satellites' positions as they appear through an inverting telescope; south is at the top.

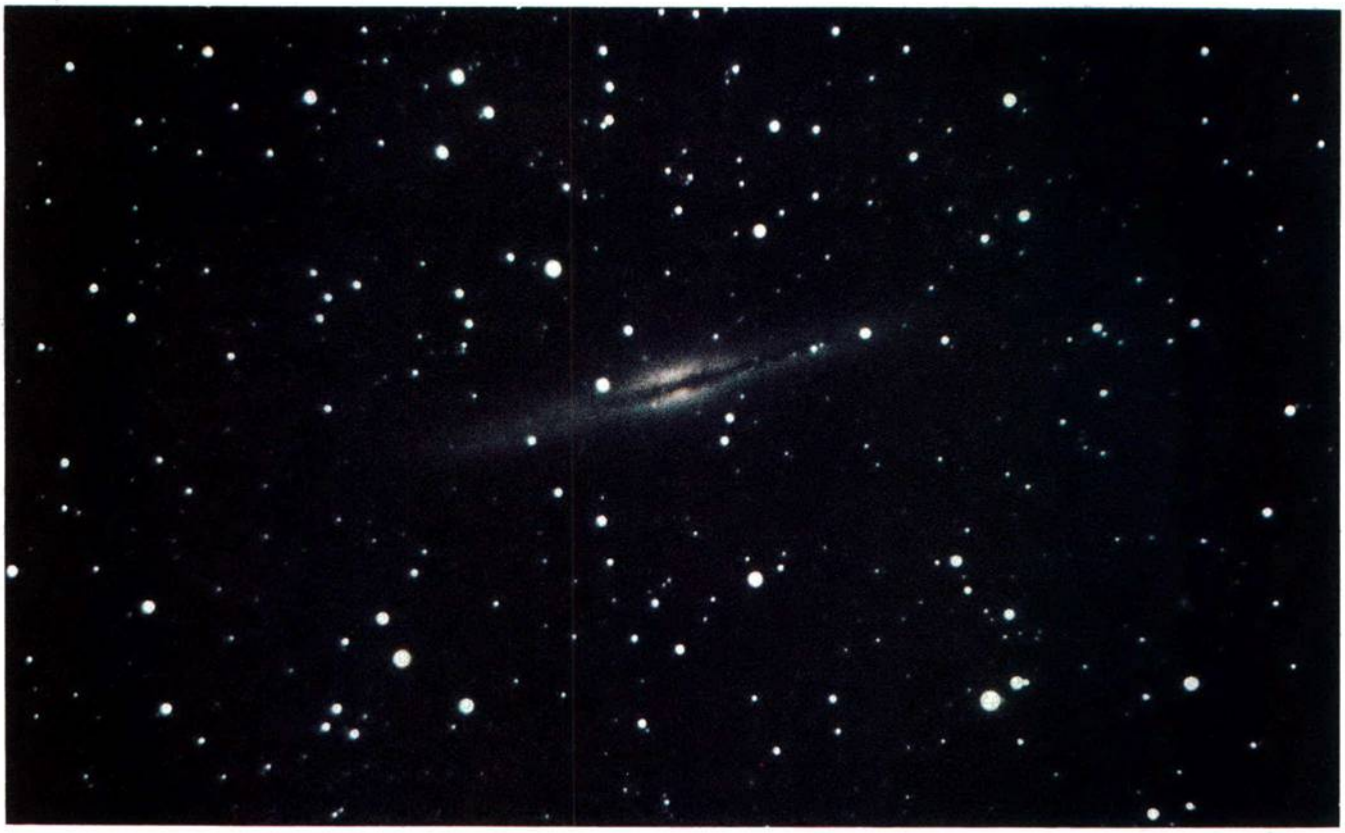
December nights may be cold, but they *are* long — almost as if nature was trying to reward you for your vigils! The nights seem to be darker and more splendid than in the months just past. Orion and his retinue rise out of the east in the early evening, and parade across the sky during the night.

The outstanding event this December will be a very lovely occultation of Venus the morning after Christmas. Mercury puts in one of its finest apparitions (as if to close out the year in style), being at one time only 25 degrees from Venus. Jupiter and Saturn fill the middle of the night. We'll bet you'll often be tempted this month to stay out the whole night through!

Mercury

An excellent opportunity to spy on our solar system's innermost planet comes your way this month. After a poor elongation in November, the planet zips between Earth and the sun on the 5th, and a day later will make its closest orbital approach to the sun (perihelion). It climbs swiftly day by day over your eastern horizon, so begin looking for it shortly after the 5th. Check this month's Gazer's Gazette for

The Trifid nebula (M-20) is a favorite subject for astrophotographers! The glorious colors from the red emission clouds of gas and the blue reflection nebula of dust make for fine contrasts, easily recorded. Compare this with the U. K. Schmidt telescope photo on page 14. Photograph by Bill Iburg.



Seen edge-on in eastern Andromeda is the distant spiral galaxy NGC-891. Very prominent are the central bulge of the nucleus and the dark lane of dust in the galactic plane. The galaxy has a diameter of some 47,000 light-years, and is receding into space at a velocity of 700km per second. Photograph by Bill Iburg.

a feature on observing the two inner planets, and a diagram showing their motions.

Venus

Unlike Mercury's quick flittings up and down over the horizon, Venus' apparitions are more stately. A brilliant jewel in the eastern sky, it will glow the brightest for this appearance on the morning of the 14th, when it'll reach -4.4 magnitude.

Get up on one of these frosty mornings and look carefully to see if you can cast a shadow by its light! You'll need to find a smooth patch of snow or other white surface that's lit by nothing but the sky and planet. Stand with your back to Venus and move around slightly — you may see a faint shadow!

You'll find more general observational details about the planet in Gazer's Gazette (page 31). But be sure to read the section below about the moon to learn about the upcoming occultation.

Earth

Twenty-one minutes after midnight EST, in the early morning hours of Dec. 22 (that's 9:21 p.m. PST, Dec. 21), the northern hemisphere officially commences winter, and the southern its summer. Earth will then be at heliocentric longitude (sun's point of view) 270 degrees, the zero point being the vernal equinox in March. The sun is now at its farthest southern declination. It'll immediately begin to crawl north again, reaching the celestial equator three months from now.

The climate machine of Earth's weather effects a time delay so that the seasonal temperatures always lag a month or two behind the sun. This fortunately moderates the seasonal extremes that otherwise could make life very unpleasant. By the time the coldest days arrive in January and February, the sun is already well back toward the equinoctial point; the increased radiation from it warms the chill of winter a bit.

Moon

The northeastern 2/3 of the United States and the eastern half of Canada will see a spectacular occultation of Venus before dawn on Dec. 26. The moon, about three days before new, will approach Venus from the west, blotting the bright planet from view.

The event will be visible north and east of a line running from northwestern Utah through the middle of Colorado, cutting across the southwestern corner of Kansas down to the southeast, eventually crossing the Florida coast near Jacksonville. If you live south and/or west of this line, you'll miss the occultation and get a conjunction instead.

Observers in the Mountain Time Zone will see the event take place around 4 a.m., Dec. 26. Those on Central Time will see it about 5:10 a.m., and the Eastern Zone's time will be 6:30 a.m. But as we suggested for previous occultations of Aldebaran in months past, these are *approximate times* only! If you want to be sure to see the event, be up and out there well in advance. Besides, the fascinating sight of the moon closing in on Venus is something you won't want to miss!

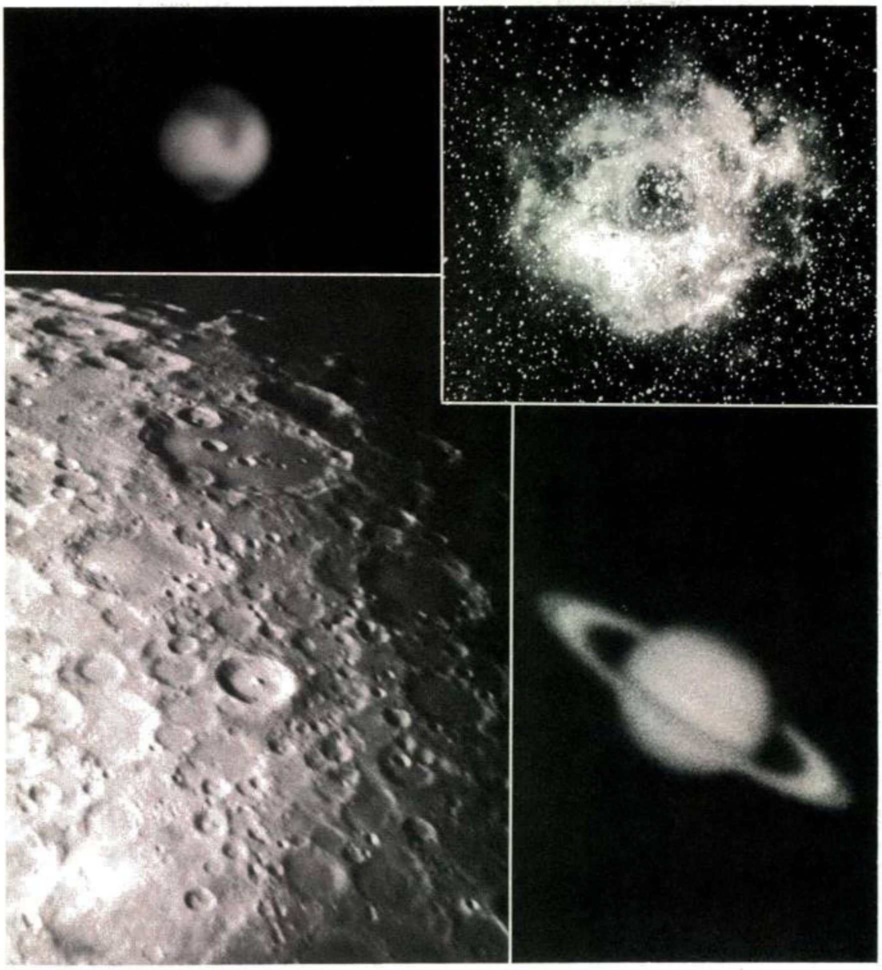
Venus will be a disk 34 seconds of arc across, but you'll need a telescope to make out its crescent shape. If you live near the southern limit line, you may see a grazing occultation. For you, Venus will glide past the southern edge of the moon, ducking in and out behind the mountains on the limb.

Be sure to send us your best pictures, and please mark the envelope with "Venus Occultation" or "Venus Conjunction".

Mars

Slowly dragging its heels, the red planet finally succumbs this month to encroaching twilight and becomes lost in the sun's glare. The long drawn out disappearance that Mars always goes through, as well as the equally long reappearance in the morning sky after conjunction, both stem from the relatively close match between its orbital speed and Earth's.

Mars orbits the sun at an average distance just over 1-1/2 times farther than Earth. This means the orbital velocity is slower, but only by 3-1/2



Top left: Mars, showing Syrtis Major. Photograph by Steve Reed. Top right: The Rosette nebula and cluster in Monoceros. Photograph by Lee C. Coombs. Bottom left: Tycho and Clavius craters. Bottom right: Saturn during March 1978. Photographs by A. Stulginskas.

miles per second (5-1/2km per second). With a speed advantage so slight, and with distances what they are, Earth has a long run to overtake Mars each time around the sun.

Jupiter

The king of planets lurks in eastern Cancer near the Beehive cluster (M-44). It now rises about three hours after sunset, and you'll pick it out easily among the stars by its -2.1 magnitude brilliance. On the 15th, its equatorial diameter will appear 41 seconds of arc across.

If you've been watching the planet closely over the last month, you'll have noticed it gradually slow its eastward motion, and then stop. Late in November, it began to move westward, back toward the Beehive, which it will pass about one degree to the south late this month. (Follow the motion in binoculars — or by naked eye, if you have a dark sky!)

Your binoculars can also show you a solar system in miniature as the four bright moons put on their lively show, shuttling from side to side of Jupiter. On the 8th you'll see all four on the western side of the disk, arrayed in numerical order from the ball outward. The same happens on 17th except that moon I (Io) is to the west, but the other three — Europa (II), Ganymede (III) and Callisto (IV) — are to the east.

On the morning of the 2nd, at about 4 a.m. EST (1 a.m. PST), Callisto's shadow will start across the disk of the planet, taking many hours to transit completely. On the 15th at about 11:45 p.m. EST, the shadow of Io will start transiting the disk. Ganymede's shadow will cross on the morning of the 27th, beginning around 12:50 a.m. EST. On the 29th, you can catch Europa's shadow beginning to cross at about 12:50 a.m. EST, with the moon itself following 1 hour 17 minutes later. All these transits last several hours, and you may not be able to follow them fully because of daylight. Still, take a look any night with a telescope and medium power (100-200x) to see what you can.

Saturn

The chief ringed planet of the sun is in Leo during December, just to the west and south of the lion's hindquarters. You'll see it easily since it's at magnitude +1.0 in a region where there are few bright stars. It rises before midnight, but you should start looking for it after about 1 a.m. since

Universal Time Is Coming!

Starting with our January 1979 issue, Sky Almanac will publish all times for celestial events in Universal Time (UT). It's a nonambiguous system of time reckoning used by astronomers in every country, and will eliminate all confusion as to just when an event is visible and on what date it falls!

UT uses a 24 hour clock, beginning at midnight, and is based on the local mean time at Greenwich, England — the world zero point for longitude measurement. Because UT stems from Greenwich local mean time, it is always ahead of either standard or daylight time in the North American time zones.

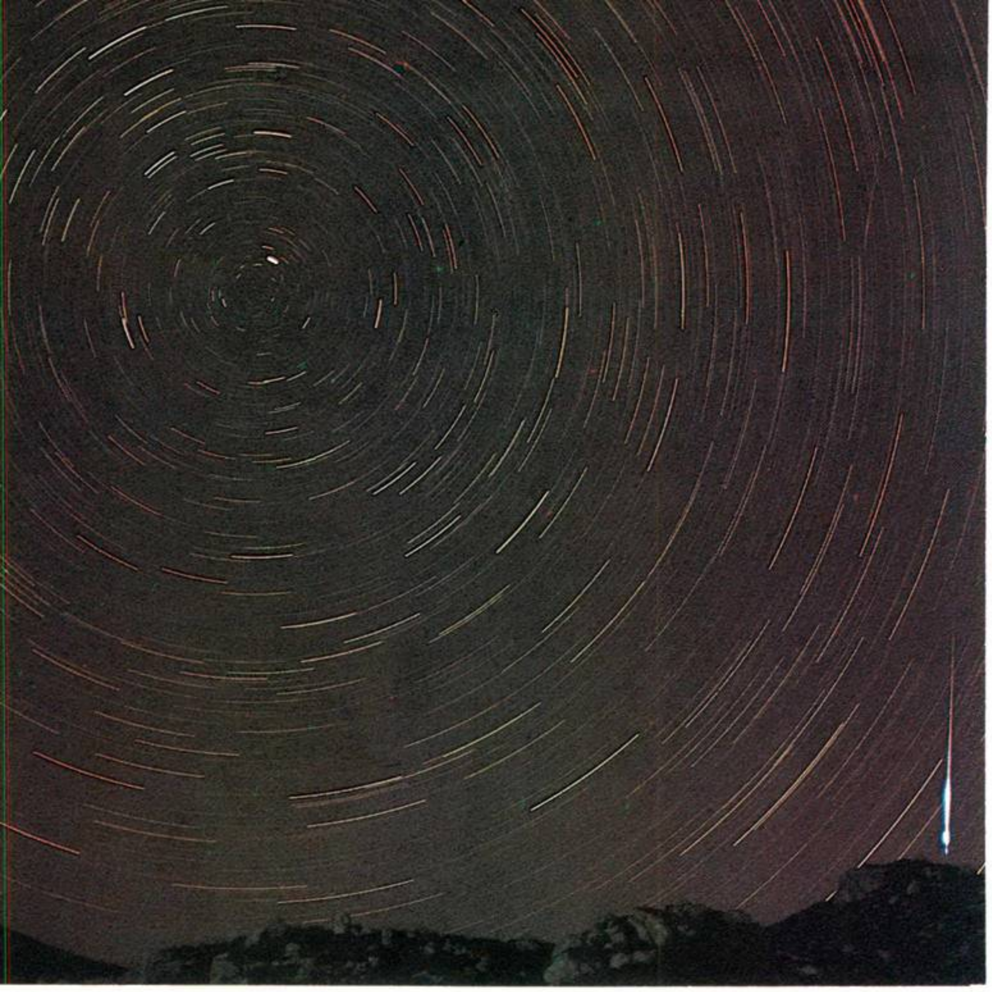
To convert UT into time for each zone in North America, you must subtract an integer number of hours. Because the conversion involves only whole hours, it's very simple.

For example, to convert UT into your local *standard* time, subtract five hours to get EST, six hours for CST, seven for MST, eight for PST, and 10 hours for Alaskan-Hawaiian standard time. To get *daylight* time from UT, take off one hour less for each zone: four for Eastern, five for Central, six for Mountain, seven for Pacific, and nine for Alaskan-Hawaiian. UT remains UT year-round; it ignores changes like daylight saving time, but because your house clock does get changed, you have to use a different conversion while daylight time is being used.

Thus, if we say an event will happen at 04:00 UT on Jan. 2, observers in the Eastern time zone see it at 11:00 p.m. EST Jan. 1. People keeping Pacific time would see the same event at 8:00 p.m. PST Jan. 1. Or, if an event happened at 02:00 UT on June 5, then in the eastern time zone, the time would be 10:00 p.m. EDT June 4. On the west coast, the same event would be seen at 7:00 p.m. PDT June 4. It's that simple!

The big advantage to UT is that we will no longer have to take up valuable space giving conversions for each zone. Also, you'll never end up looking for an event a day early or late if you follow the conversion as given above. Each issue will include a short description of UT with conversion examples, so you'll always be able to refer to it. (UT and other astronomical time keeping systems were described in the July 1978 issue.)

This month, like last month, space constraints forced us to drop our Planet Finder. We were sorry to do this, but had little other choice. However, starting next month you'll see a new, revised and far more useful Planet Finder! Watch for it!



Dramatically caught at the very edge of the camera field, this Perseid streaked across star trails in the northeastern sky. The exposure ran for 55 minutes at f/2.8, with a 50mm lens and ASA 400 film. Photograph by Martin Anderson.

only by then will it have risen enough to be seen clearly. At midmonth, the ball is 16 seconds of arc in size, with the rings nearly edge-on, spreading out 41 seconds.

Like Jupiter, Saturn is slowing its eastward motion prior to making a westward, or *retrograde*, loop in the sky. The loop is an optical effect caused by Earth's overtaking a slower, outer planet in its sweep around the sun. For Saturn the halt comes on the 25th; thereafter until early next May, it'll creep slowly westward, passing through opposition on March 1.

Saturn's brighter moons can be followed in a small telescope (Titan, the brightest, can be seen in binoculars). You'll find them most easily around the times of their elongations to one side or the other of Saturn. Look for Titan at eastern elongation on the 6th and 22nd. Western elongations come on the 13th and 29th. You're looking for an 8.8 magnitude speck of light about 4-1/2 ring diameters from the planet.

Rhea, a bit harder to see at magnitude 10.2, moves around the planet in about 4-1/2 days, much faster than Titan's 16 day orbit. Watch for Rhea at eastern elongation (the separation is two ring diameters) on the 1st, 5th, 10th, 14th, 19th, 23rd and 28th. Western elongations happen in between, and have the same separation.

Iapetus, probably the oddest moon in the solar system, is much brighter at western elongation than eastern — by 1.75 magnitude! Last month there was a western elongation; this month you get an eastern one. (Iapetus orbits Saturn with a 79 day period.) Its magnitude on the date of elongation, the 16th, will be 12.3. No one yet knows why half the moon should be darker than the other. Pioneer 11, scheduled to fly by Saturn in the fall of 1979, may help resolve the matter.

Uranus

Uranus has returned to view in the morning sky, but its proximity to the sun makes its visibility poor. On the 24th, it'll be three degrees south of Venus at magnitude 5.9. You'll need a telescope to make out its 3-1/2 second of arc disk.

Neptune

Neptune is even closer to the sun than Uranus. You should look for it on the morning of the 31st, just north of Mercury. It's 2.3 seconds of arc in diameter and at magnitude 7.8.

Geminid Meteors

The Geminids arrive annually in plentiful numbers, but this year the full moon on the night of maximum will reduce the numbers a lot. Peak time is the morning hours of the 14th when they should be arriving at 50 per hour. At the least, you'll see the brighter ones if you get up to watch.

The Geminids are fairly slow meteors (22 miles per second, or 35km per second), and the shower peaks relatively rapidly. The radiant point lies in Gemini (hence the name), close to Castor and Pollux, the two brightest stars in the constellation.

Ursid Meteors

The Ursids are not an outstanding shower, having about 15 meteors per hour. In addition, the peak (which comes on the 22nd) will have a third quarter moon to light the skies. But since the radiant is up in the bowl of the Little Dipper, and the moon is well away from it, you may spot adequate numbers of these meteors.

Upcoming Events for January

3	Quadrantid meteors
4	Earth at perihelion
5	First Quarter Moon
13	Full Moon
18	Venus greatest western elongation
20	Mars in conjunction with sun
21	Last Quarter Moon
24	Jupiter at opposition
28	New Moon

The Quadrantid meteors promise to be free from moonlight — something any dedicated meteor watcher will welcome! The show is moderately rich and peaks quickly, so be ready late on the night of Jan. 3-4.

Jupiter's opposition means that you can re-acquaint yourself with the planet — if you haven't already. The way the brightness of the planet increases toward opposition is intriguing: Over the months it steadily grows until suddenly you notice that it has far outstripped every star in its vicinity. If you haven't looked for it in a while, the increase can be very surprising!

GAZER'S GAZETTE

Watching the Inner Planets

by

Robert Burnham

Hanging in the morning sky this month are the solar system's two innermost planets — Mercury and Venus. You have been presented, by grace of the immutable laws of celestial mechanics, with a golden opportunity to get to know these two worlds! We've prepared finder charts for this month's morning apparition of the two planets and the evening appearance of Mercury coming later this winter. Whether you're an old Mercury spotter from way back, or have just become interested in astronomy, now's an excellent time to get up a bit early and see the sights!

Mercury

Date		Magnitude	Phase (%)	Apparent Diameter (seconds of arc)	Distance (millions of miles)
Dec.	10	+1.6	5	9.5	65.7
	14	+0.7	20	8.6	72.0
	18	+0.2	41	7.8	80.1
	22	0.0	55	7.0	88.5
	26	-0.1	65	6.4	96.6
	30	-0.2	71	6.0	103.9
Jan.	3	-0.2	80	5.6	110.2
	7	-0.2	85	5.4	115.6
	11	-0.3	88	5.2	120.2
Feb.	21	-1.2	94	5.2	118.6
	26	-1.0	84	5.7	109.7
Mar.	3	-0.7	68	6.3	98.4
	8	-0.1	46	7.3	85.5
	13	+0.7	25	8.5	73.2
	18	+1.7	9	9.8	63.3

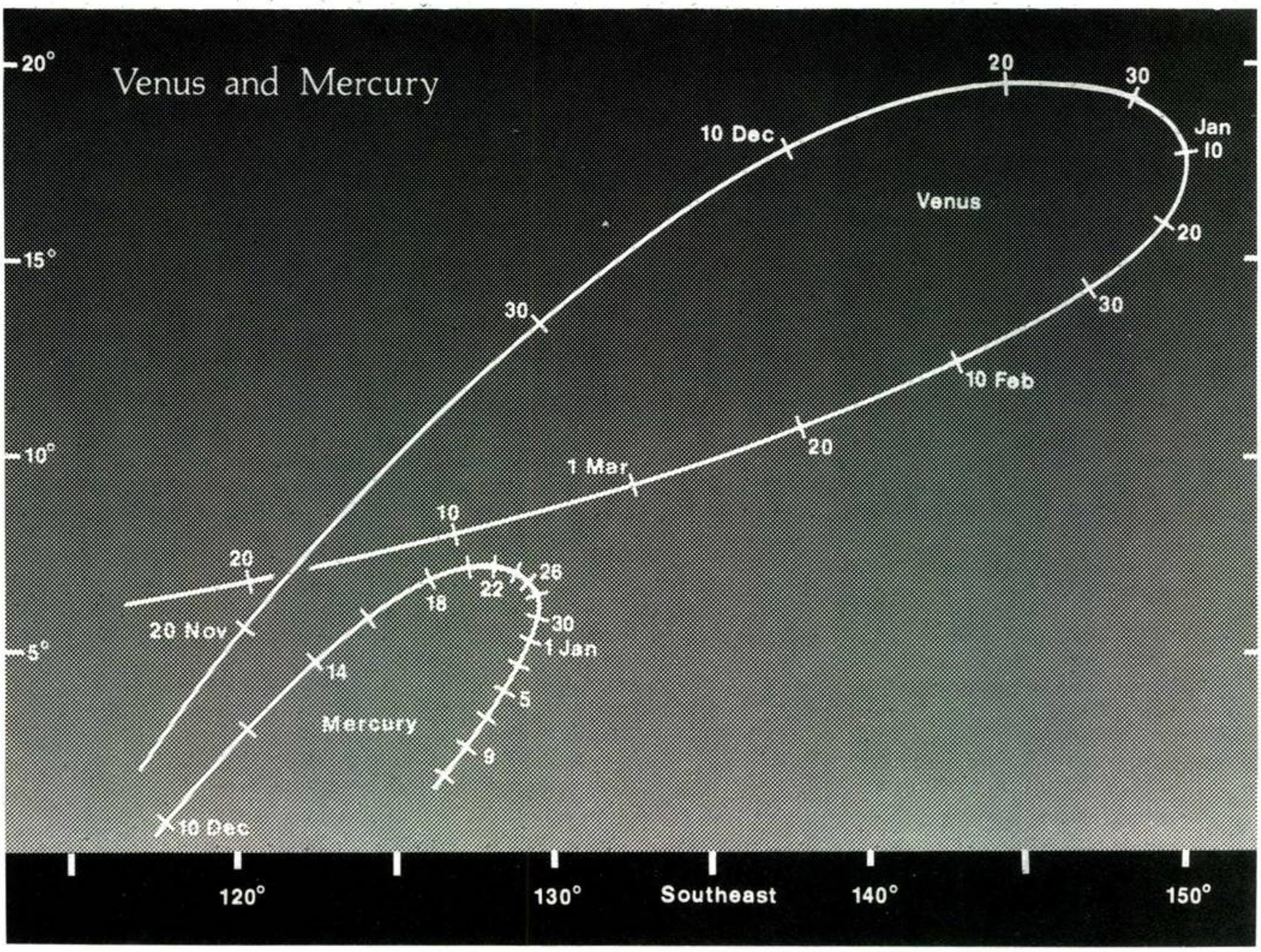
Venus

Date		Magnitude	Phase (%)	Apparent Diameter (seconds of arc)	Distance (millions of miles)
Dec.	10	-4.4	23	43.4	36.0
	20	-4.4	31	37.0	42.3
	30	-4.3	38	31.9	49.0
Jan.	10	-4.2	44	27.6	56.6
	20	-4.1	51	24.5	63.8
	30	-4.0	55	22.1	70.8
Feb.	10	-3.9	61	19.9	77.9
	20	-3.8	64	18.3	85.5
Mar.	1	-3.7	67	17.1	91.6
	10	-3.6	71	16.0	97.6
	20	-3.6	74	15.0	104.0

The simplest equipment is the best. If you have binoculars, for example, use them, as they'll make finding and following Mercury a lot easier. They'll also be handy when you're searching in the brightening dawn for a speck of light. But even if all you have are your two eyes, you'll still be able to see something. Don't forget that Mercury's motions were well known to the ancients who, of course, had no telescopes!

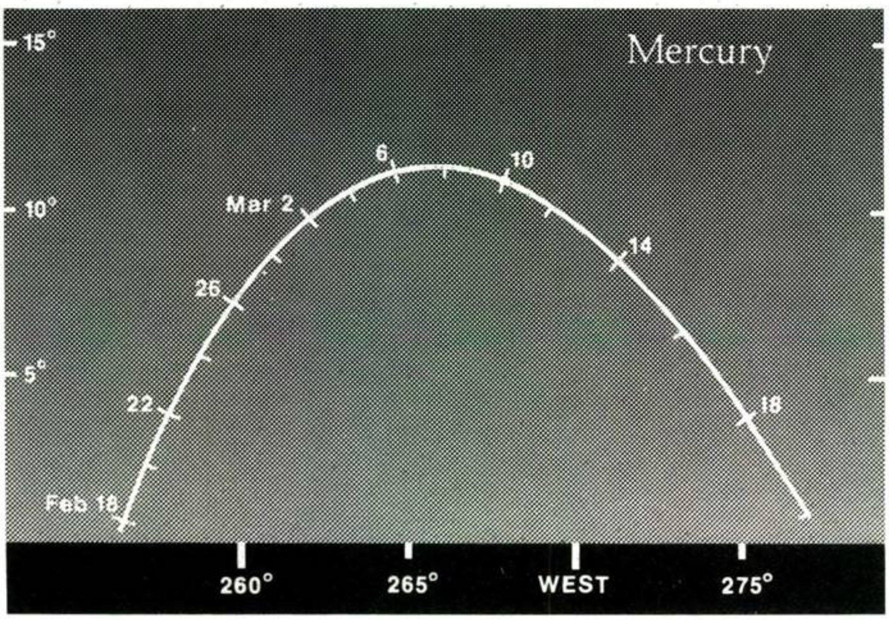
On the other hand, you'll have no trouble at all spotting Venus: It's the brightest object in the sky apart from the sun or moon! On Dec. 14, when it reaches greatest brightness, it'll be magnitude -4.4. The relatively abrupt appearance of Venus in the morning sky after it's passed between Earth and the sun often causes some amount of public notice. People who have become used to seeing it in the evening sky suddenly see this bright object in the morning, and aren't always certain that the two are really one and the same. Phone calls follow to the police and newspapers, and UFO reports increase. But it's only a bright planet, though it sure does grab your attention!

What's happening to put on the show? Why do these two planets shunt back and forth from evening to morning? Why can't you see Mercury at midnight? The answer to all these questions lies in the fact that the two orbit the sun closer than Earth does.



The morning sky this winter is shown in the diagram above. An observer at 40 degrees north latitude facing east a half hour before sunrise would see Venus and Mercury describe these paths over the dates shown. Notice how quickly Mercury comes and goes compared to Venus' stately progress!

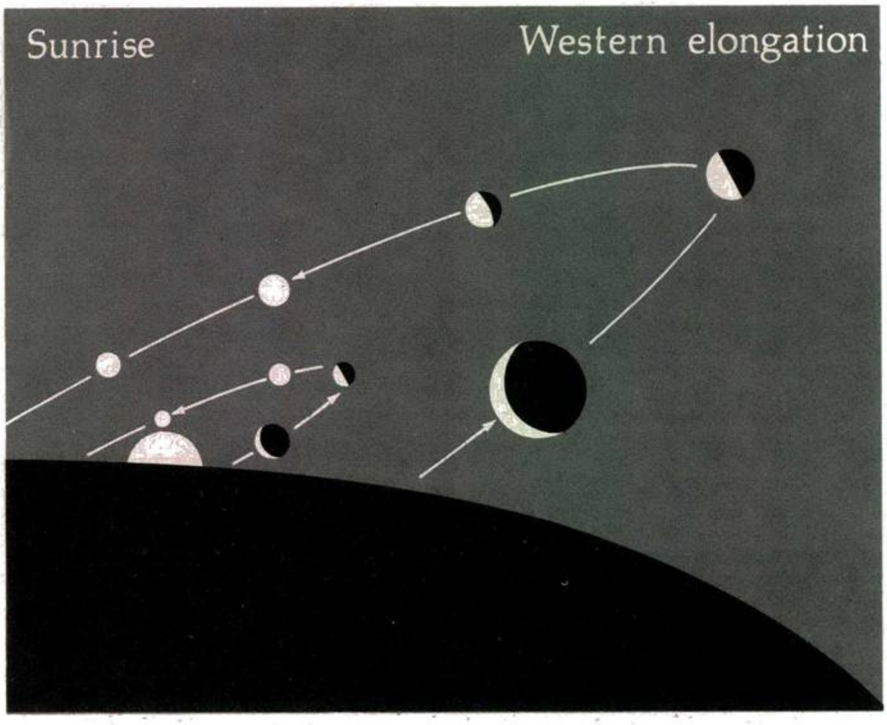
Below: Mercury's evening appearance late in winter will look like this to an observer facing west, 30 minutes after sunset. Reaching maximum elevation on the 8th, it starts to accelerate down toward the sun thereafter.



We stand at a vantage point some 93,000,000 miles from the sun. We look inward toward the sun, and periodically one planet or the other swings to the left or right (east or west) of the sun's fierce glare. It's only when the object gets far enough away from that glare that we can catch sight of it.

Mercury circles the sun at an average distance of some 36,000,000 miles. But because this average is only that, and because the orbit is markedly elliptical, the real distance varies from 29,000,000 to 43,000,000 miles. From our viewpoint, that means Mercury's separation (or elongation) at greatest can vary from 17 to around 25 degrees. Obviously some maximum elongations will be better than others. Equally clear is the fact that since Mercury stays within 25 degrees of the sun, it will set or rise close to it. You'll always see Mercury in a twilight sky, except during a solar eclipse.

Some elongations are better than others for a reason besides that of separation: elevation over the horizon. Mercury, like almost all the planets, has an orbit that's angled only slightly to the ecliptic (the plane of Earth's orbit). But because the ecliptic itself is angled to the celestial equator, half the year it runs to the north of the equator and half to the south. The extreme range covers almost 50 degrees! When the ecliptic lies to the north, any planet on it will have a relatively high elevation for observers in the northern hemisphere. When it's south, the elevation for them is low. Unfortunately, when Mercury is at its greatest elongation from the sun (an aphelic elongation), it's also at a point in its orbit about as far below the ecliptic as it can get. In addition, this happens at a place in orbit where the ecliptic itself is far south of the celestial equator. The meaning of all this for northern hemisphere observers is that Mercury is low when it's far from the sun and high when it's close in. We're at a disadvantage all around, but you can make best of it when you get an evening (eastern) elongation in spring and a morning one in autumn. This month's elongation is sort of in between, being 22 degrees wide and halfway from the best to worst time.



Above: In a generalized way, this shows the geometry of a western elongation for the two inner planets. The phases they undergo and the changes in apparent size are seen clearly. However, the actual path in the sky will depend on several factors: time of year, inclinations of orbits and observer's latitude.

Venus suffers little from this. It orbits in a near perfect circle at a distance of 67 million miles. Its maximum elongations come to about 47 degrees, and while you won't usually see it very late, it does gleam from a fully dark sky. For northern hemisphere observers, it'll reach its maximum elevation during spring evening elongations — on rare occasions being visible until midnight!

Venus' appearances are leisurely affairs. Over many months the planet draws slowly out of the sun's glare in the evening hours, reaching at some point a maximum elevation. Then it begins to move in toward the sun, growing brighter all the while. About 35 days before it passes between us and the sun, Venus reaches a peak brightness. After inferior conjunction, it moves swiftly into the morning sky, again becoming very bright 35 days later. Venus then moves more and more slowly away from the sun, out to maximum elongation. Over several months it crawls back toward the sun and eventually passes it on the far side, starting the process anew.

Mercury's motions are far more rapid: Instead of taking 225 days to circle the sun as Venus does, it zips around in 88! Observers find this advantageous, for if you miss it on one apparition, you soon get another chance.

Mercury's magnitude never comes close to that of Venus. At maximum elongation in December it will be -0.2 magnitude; in February-March, -1.0. This is bright, but not as bright as you'd expect considering that Mercury, being closer to the sun, has sunlight falling on it that's 3-1/2 times stronger! The explanation is that Mercury's very like our moon in terms of surface composition and reflectivity, sending off only six percent of the light falling on it. Venus, though farther from the sun, is whiter: It reflects fully 72 percent of the light. And also, as seen from Earth, it's angular size becomes much larger in the sky.

If you have a telescope to turn on the two planets, you'll be treated to an impressive sight of their changing shapes and sizes — especially of Venus! Both the inner planets show phases like the moon's — a curious fact first noted by Galileo who spotted the effect on Venus, and which is visible with low power.

The diagram above shows what phases you'll see in a general way, and the geometry causing the phases is shown. The table of facts given on the first page of the article tells you how much of the planet is lit and the apparent angular size for a number of dates throughout the apparitions.

When you set up with your telescope, keep in mind that you may have to locate the planet(s) in binoculars. The finderscopes on many telescopes don't have a very wide field of view; looking through them can be like peering through a tube of cardboard! When you find the planet with binoculars, aim the finder at it, finally centering it in the eyepiece. (When you are looking for Venus, this procedure isn't necessary for the most part since it's so bright.)

Do you have a small scope? Are you worried about what you'll see? Relax! A 60mm scope will have less problems from atmospheric turbulance (seeing) than an 8 or 10 incher will, all else being equal. The turbulance cells in the air are much larger than your 60mm objective lens, so as a result, the image jumps around a bit, but stays relatively sharp. In a big scope, the image is steadier overall, but fuzzier.

However, you ought to remember you're looking out through a lot of atmosphere! You just aren't going to get a crisp image most of the time. Mercury will never be very good, but Venus can be amazingly steady if you catch it when high in the sky. You'll be dazzled less if you look when twilight is pretty bright.

If you have trouble finding Mercury, which can happen easily in the bright dawn sky, get up a little earlier and try using Venus as a reference point. Around Christmas, they'll be less than 25 degrees apart: Offsetting from bright Venus may help locate dimmer Mercury. (Don't overlook the occultation of Venus on Dec. 26; see this month's Sky Almanac for details!)

If getting up before dawn sounds horrible to you, remember that in December sunrise comes pretty late. Many people will be up and on their way to work while it's still dark. Take a few extra minutes and try for Mercury! In any case, locating and following it for a few days or a week is an exciting challenge, accompanied by the blazing spectacle of Venus. Whatever your level of interest or experience, there's something for you in the morning sky this winter — don't miss it!

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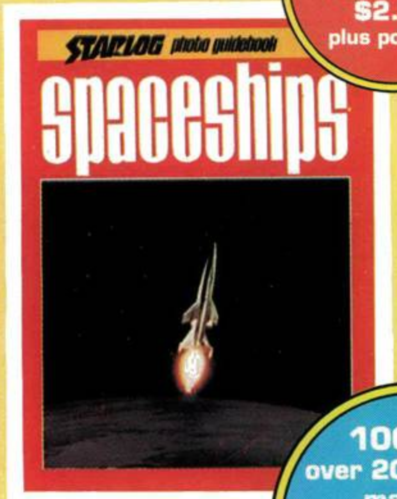

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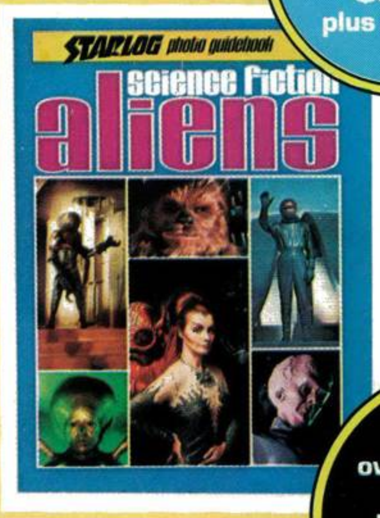

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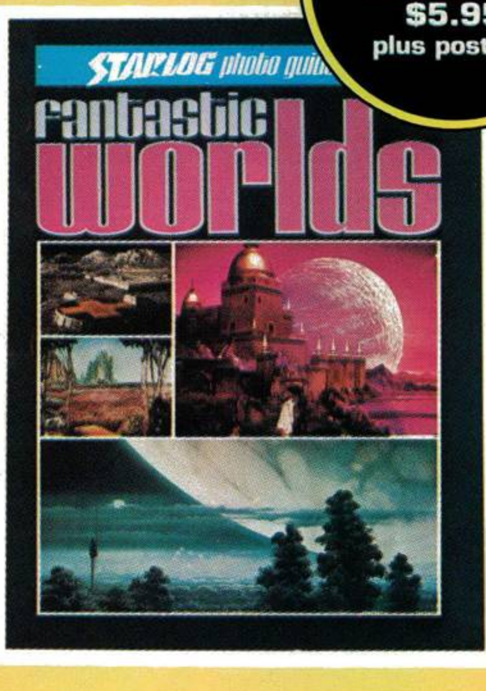

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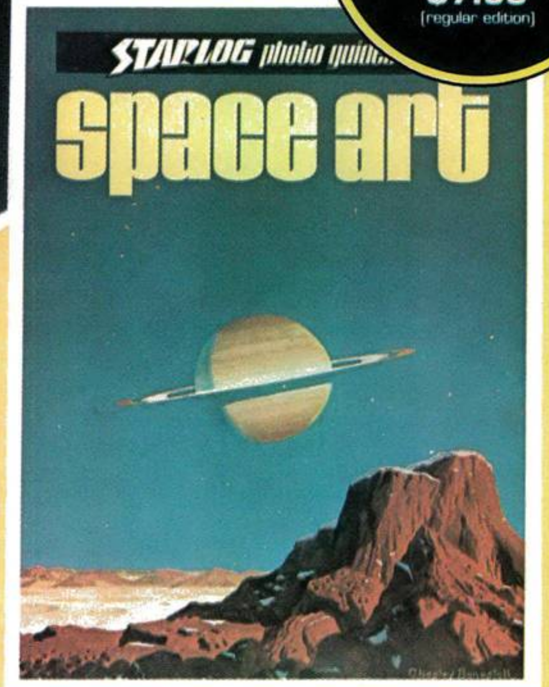

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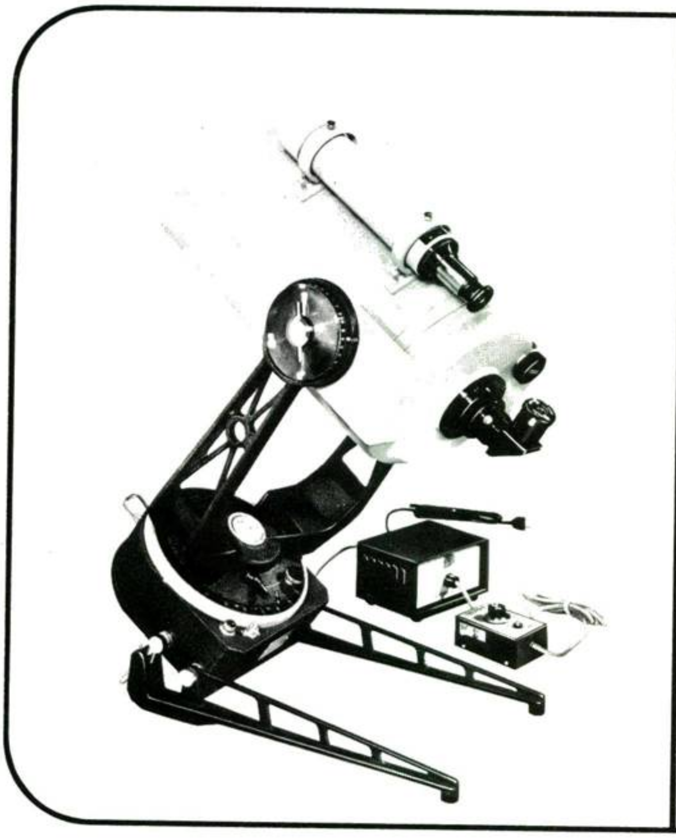

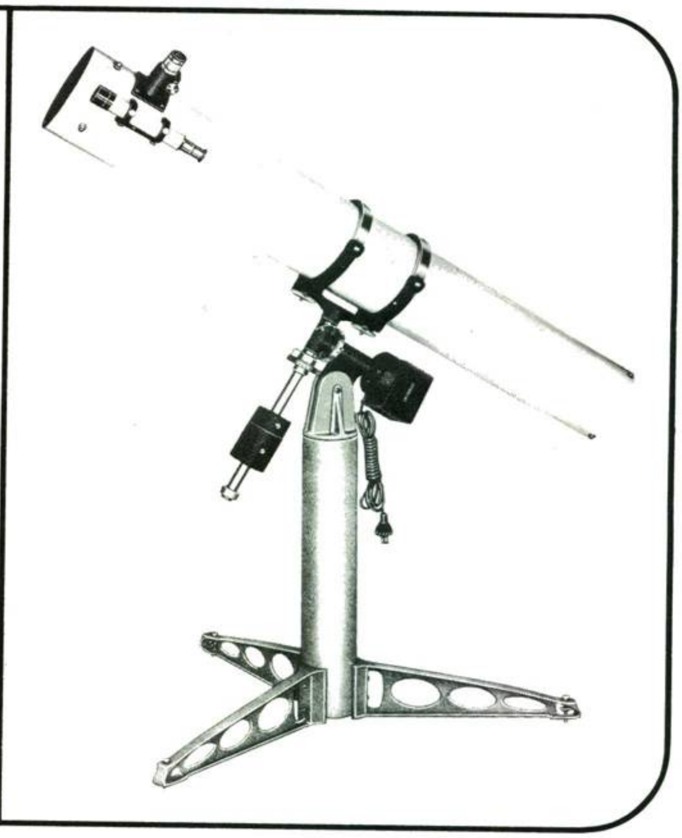

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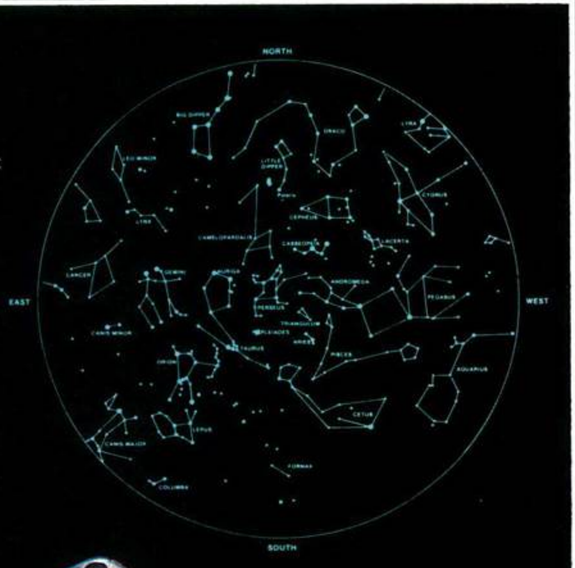
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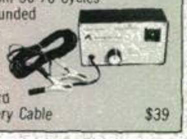

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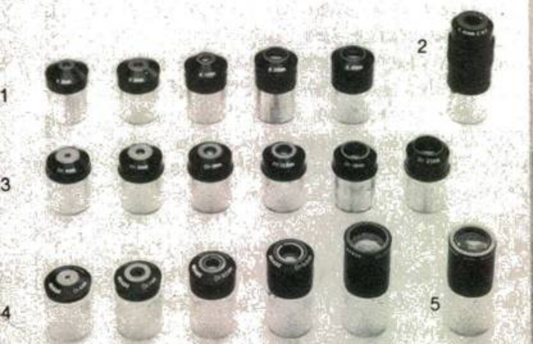

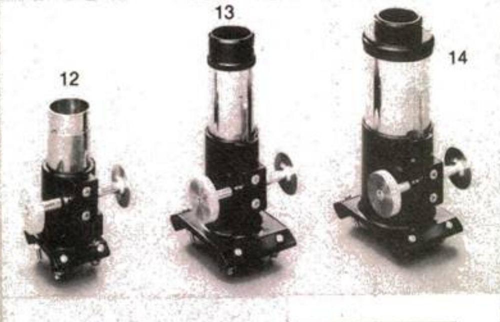

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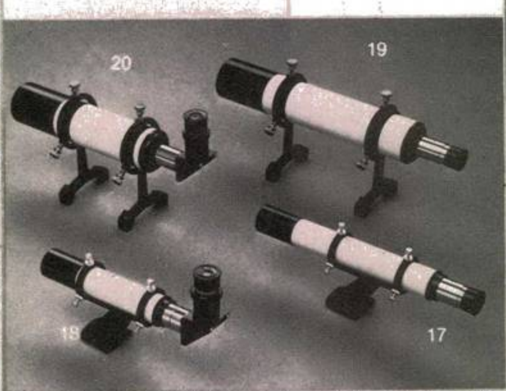

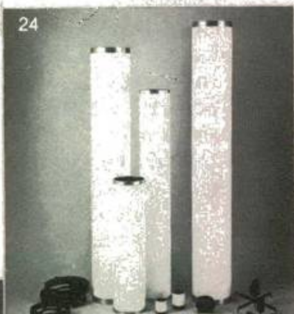

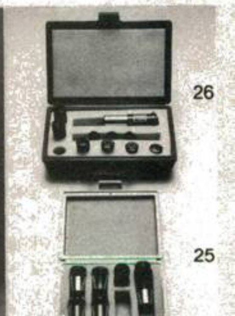

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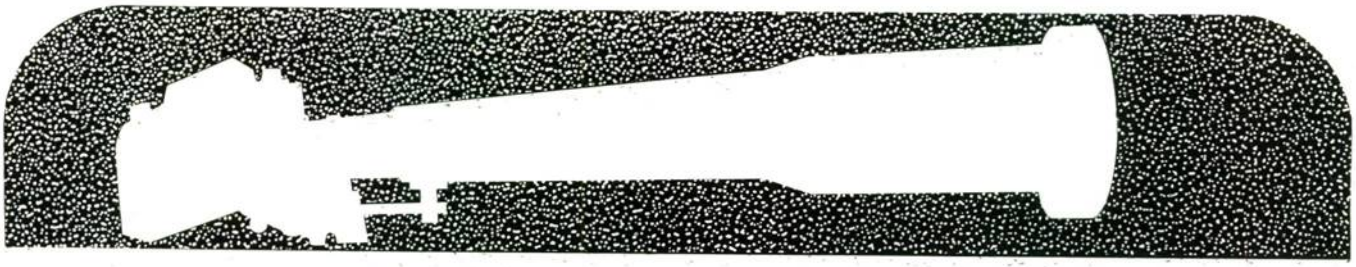


The Wet Side of Color Astrophotography

by
Bill Iburg

With today's modern color chemistry, developing color slides or prints can be done — out in the light — right in your own kitchen! The only darkroom you'll need is a small closet for handling the film and exposing the printing paper. Expensive and tricky equipment? None is needed! Today, color photography is almost as easy as black and white. Applied to astrophotography, color is now a serious competitor to black and white.

The three most common methods of color astrophotography are: using off-the-shelf color slide film in a 35mm camera, hydrogen hypersensitizing these films for greater sensitivity, and cooling the emulsions in a cold camera. Another superb technique — though not very common — involves taking three pictures of the same subject on black and white film in red, green and blue light, and then superimposing these onto one color print.

Using color film right off the shelf will not produce the best results, but it can be a beginning. Color films tend to be quite slow for long exposures and usually have poor reciprocity failure, meaning they don't store up much light over long exposures. The color balance may tend to shift rather drastically. One good choice for this type of color work is Fuji R100 slide film.

More About Color Photography

Bob Mitchell, *Color Printing*, Peterson Publishing Co. (1975).

Tom Burke, *Do It In the Dark*, H. P. Books (1975).

One way to increase sensitivity while maintaining good color balance involves cooling the film to -40 degrees Fahrenheit (-40 degrees Celsius) in a cold camera. In conjunction with Kodak Ektachrome 200 film, this technique has yielded some of the most beautifully balanced color astrophotos ever produced. Excellent articles on cold camera techniques can be found in ASTRONOMY, February and March 1977.

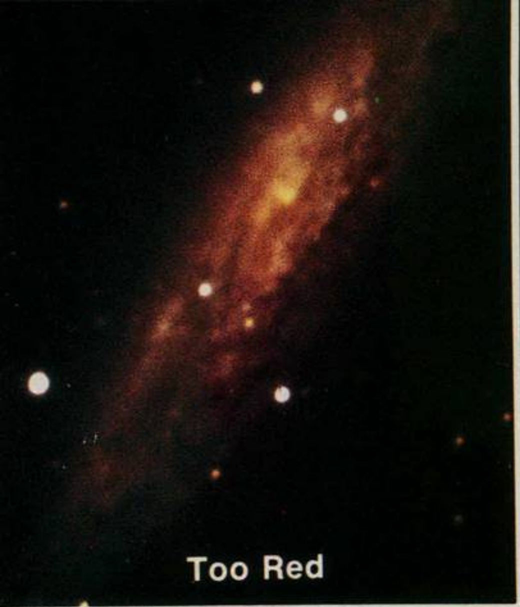
Hydrogen hypersensitizing involves exposing the color film to a hydrogen atmosphere for a period of time before the film is taken into the field to be used. This technique has yielded good results, but the necessary apparatus, tanks of gas, and danger of explosions may be more than the average astrophotographer is willing to handle.

The color process is simplified greatly if you stick to slide film — such as Ektachrome 200 in a cold camera, or Fuji R100 in a 35mm camera (or cold camera for red objects!). Slide film offers one important advantage: You can see the color rendition simply by holding the slide up to the light. When you make the final print, it's then quite easy to compare the print to the slide and see what direction, if any, your color correction should follow.

Once you've exposed the film, you have either a roll of color film or small sections of film cut three or four inches long (used in some cold camera designs). Now, how do you get from this point to those beautiful prints?

Begin by going into a darkroom — such as a closet — and loading your film onto the reel of a developing tank, preferably the plastic inversion type. This type of reel will help keep the film chips (if you've used a cold camera) from sliding in front of one another

Color printing affords flexibility that slides alone cannot offer. By adjusting the filtration of the light, you can correct off-color images in printing. Here, surrounding a correctly color balanced image of NGC-253 made with a Celestron 14 telescope and cold camera, are the six basic color errors. The top row shows the additive primary colors (red, green and blue) and the bottom row shows the subtractive primaries (yellow, magenta and cyan). Photograph by Bill Iburg.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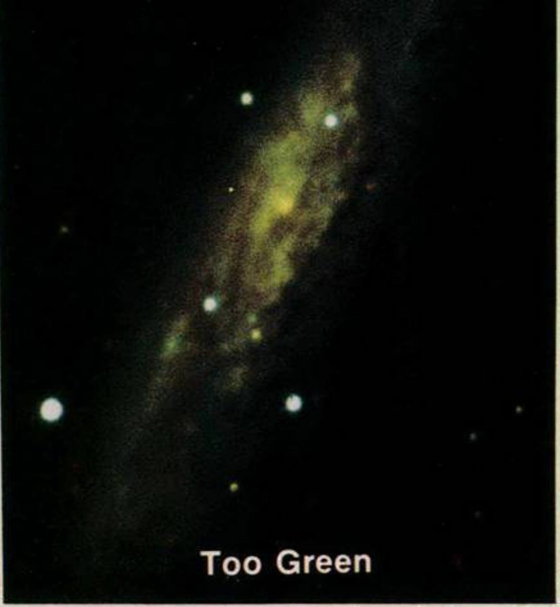
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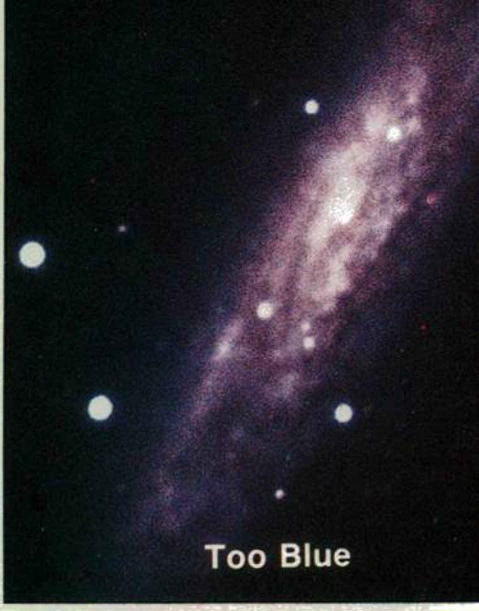
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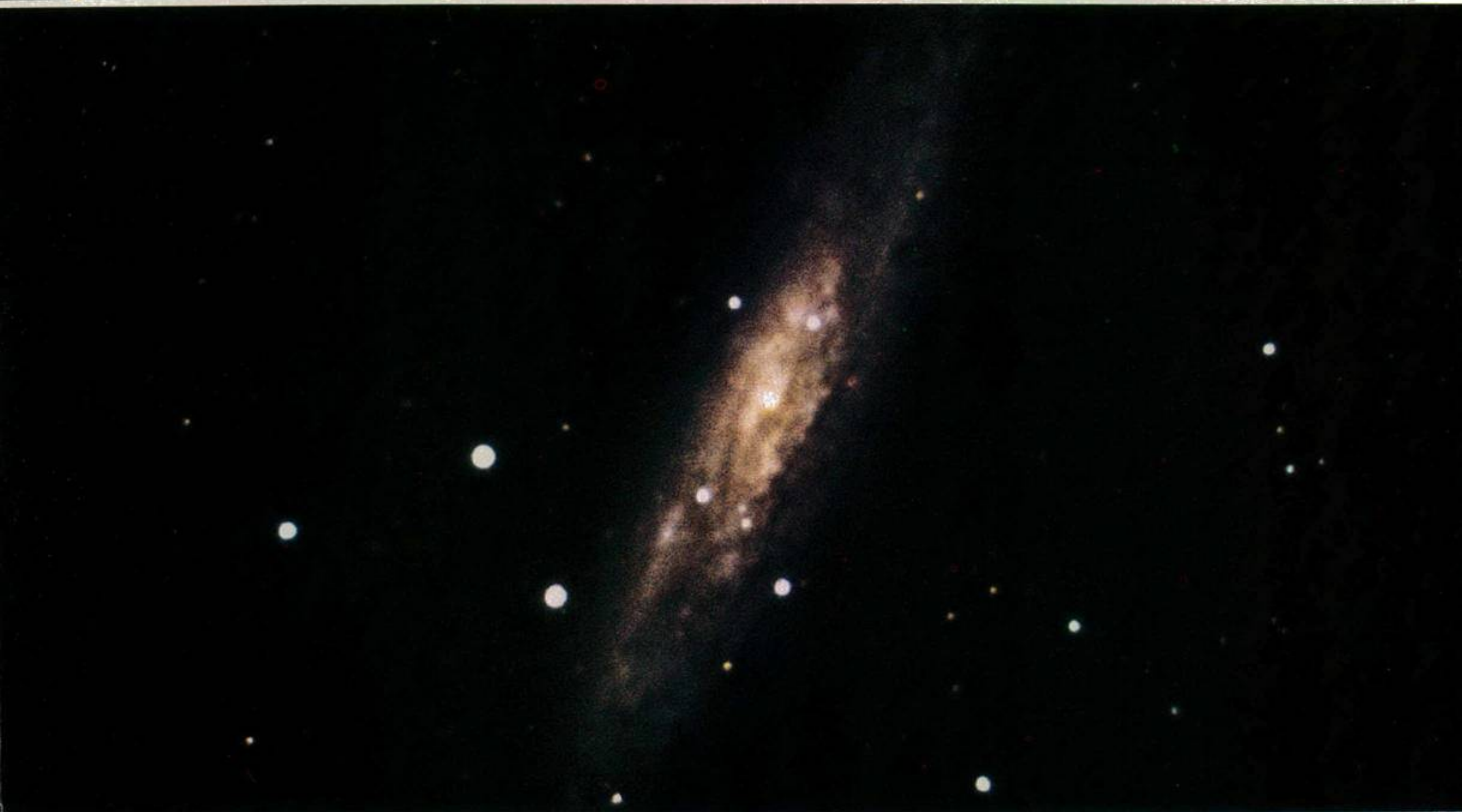

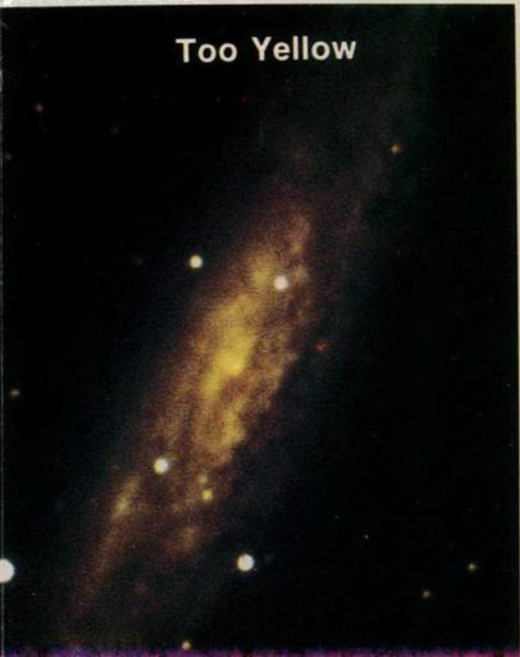
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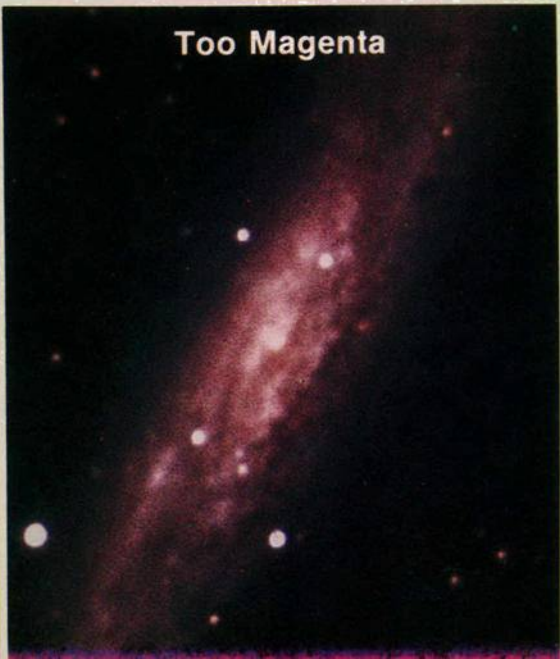
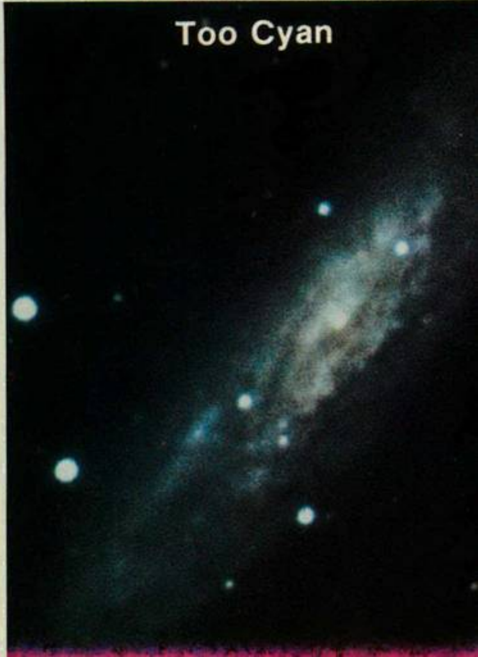
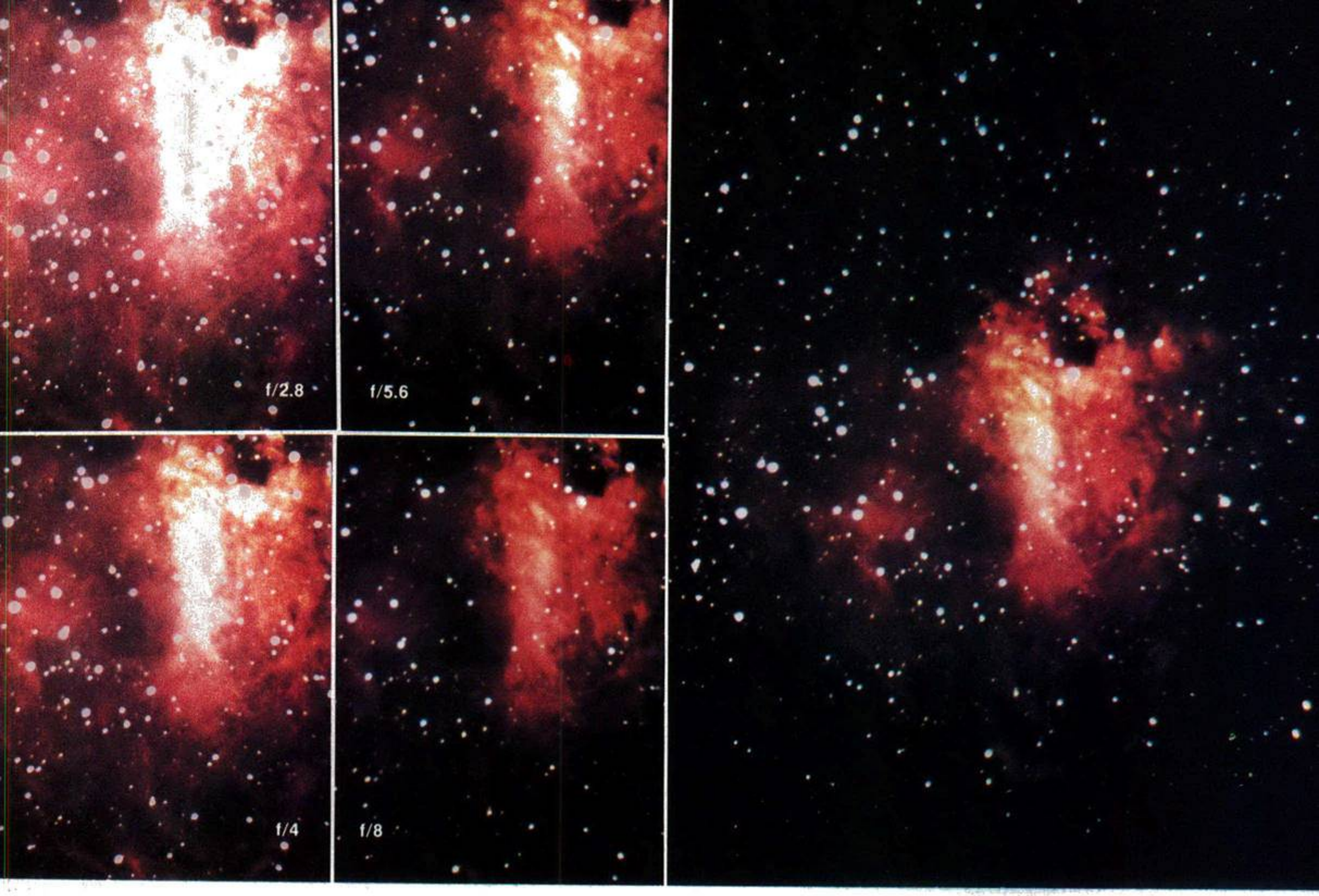

Too Magenta


Too Cyan



Finding the proper exposure time involves making a test sheet at a series of different enlarger lens openings. The best exposure is a compromise between picking up fainter nebulosity while retaining detail in the brighter portions of the image. The best print in this sequence seemed to be the one made at f/5.6, shown in its entirety at right. Photographs by Bill Iburg.

during developing. Another good trick is to slide the chips on (each in their own track on the reel), move them all to one side of the reel, and press a number 6-1/2 rubber stopper onto the other half to prevent the chips from interfering with one another.

Unicolor slide processing chemicals are the most convenient and least time consuming developing chemistry to use and they yield good color balance. (For the *very* best results, however, stick with Kodak's E6 chemistry; after all, they know the most about their film!) There are seven chemicals in the Unicolor E6 kit, and the best way to use them is to mix the required amounts (16 ounces) into clearly labeled plastic pint bottles.

Color developing has a reputation: You must maintain the proper temperature to the nearest millionth degree or all your photos will come out purple and orange! Not so. An easy way to maintain good temperature control to the kind of ±1 tolerance required, is to fill your bathtub with 100 degree Fahrenheit water (required for this process), place all the plastic bottles (tightly capped, of course) into the tub, and wait about 1/2 hour. During this time check to see that the temperature stays at 100 degrees by adding more hot water if necessary. You're ready to develop when all the chemicals reach working temperature.

Then simply run through the developing steps clearly outlined in the instructions supplied with the kit. This involves pouring in, agitating, and dumping out your solutions in the prescribed order for the necessary length of time, totaling about 30 minutes. Leave all solutions in the tub during this process, removing them one at a time as you work through the procedure. At the end of these steps, open the tank, hang the film up to dry for a couple of hours, and your filmstrip is finished! All that remains is to cut it to proper size and mount the strips into slide holders such as Kodak Ready-Mounts. Be sure to write all necessary exposure data right on the mounts so it can't get lost. Even if you didn't want to make prints, you already have the makings of a first class slide show. You can't do that with black and white negatives, unless you enjoy looking at a white sky with black stars!

But assuming you do want those beautiful color prints, slides are not the final stage of the process. For printing them you will need the following: a dark room (such as a closet) where you can work in total darkness, a simple enlarger with lens capable of holding a slide and a color filter drawer for 3 x 3 inch color printing filters, a set of color printing filters, a stopwatch, a thermometer, Cibachrome 8 x 10 color print paper, a color paper developing drum, Cibachrome developing kit, an easel for holding the paper while exposing the print, 1,000 and 150ml graduated cylinders for mixing chemicals, and a sink with running water (which need not be in your darkroom). You will probably also want the Cibachrome printing manual — somewhat expensive but very useful.

The real beauty of Cibachrome is that you start with a positive (the slide) and go directly to a positive (the print). You never have to worry about orange on the negative being green on the print, or blue being red — or was it yellow? Also notice that you don't need $800 for an enlarger with a fancy built-in color head or another $300 for a good color analyzer. You don't need these with the Cibachrome process.

To begin, set up for enlarging in a light-tight room — any room will do as long as it's completely dark after you switch the light off. Leave the developing chemicals, graduated cylinders, and thermometers beside the kitchen sink. You don't need a "safelight", either; color paper is sensitive to most any color light, so exposing the print must be carried out in total darkness. This will be a little inconvenient at first, but you'll easily become accustomed to the technique.

Your first print will be a "test print" to determine proper exposure and color balance. To do this, you'll need two pieces of opaque cardboard — one full 8 x 10 inch piece to cover the paper, and another 8 x 10 with a 4 x 5 inch corner cut out of it. This second piece is used to expose the paper in four different places for your test prints.

If you examine your color printing filter set — such as the one by Unicolor — you'll see a series of cyan, magenta and yellow filters of varying densities such as .025, .05, .1, .2, .4 and .5, and a UV filter to remove this unwanted component. These are the filters for adjusting the color balance of the final print. On the back of the paper package you will see listed a basic filter pack for various types of films. These numbers vary with differing batches of paper, so when you buy new paper, be sure to use the filter pack listed on the back of that particular package. This basic filter pack is your starting point.

Note the filters needed for the type of film used — such as .50 yellow (Y), .00 magenta (M, meaning no magenta), and .25 cyan (C) for Ektachrome film. Select these filters along with the UV filter and place them all in the filter drawer in the enlarger. Dust off the slide and place it in the slide holder, emulsion side down. Rack the enlarger head all the way up and set the lens to maximum opening, usually f/2.8 or f/4. Place the back side of a used 8 x 10 print on the easel and set the easel under the lens. Turn off the lights and switch on the enlarger. The image shining down on the white paper will be dim but easy to see. Place the 8 x 10 inch piece of cardboard with the 4 x 5 cutout on top of the paper, and position the main subject of the slide in the center of the cutout portion of the cardboard. This is done by moving the easel around under the lens until the subject is in the desired position. Focus the enlarger carefully while watching the subject on the paper.

Now you're ready for the real thing. One word of caution: Be sure you have the developing drum with you in the room. There is nothing more embarrassing than exposing your print and groping around in the dark for the drum, only to find that you left it in the kitchen after developing the last print!

With the lights out, open up the paper package, remove a single sheet, and place the *smooth* emulsion side up on the printing easel. Be careful not to disturb the position of the easel while placing the paper on it. Turn on the enlarger and expose the paper for 60 seconds. Obviously, you'll need a stopwatch or timer that glows in the dark, facing away from the paper. Repeat this process three more times — exposing a different corner of the paper each time — using the cutout in different positions and closing down the lens one stop for each exposure. (After you develop the test print, you'll see four prints on one sheet of paper, each at a different f/stop, all exposed for 60 seconds.) Remove the paper from the easel, place it in the developing drum with the emulsion side facing inward, cap the open end, turn on the lights (in that order, please), and you're ready to develop.

The developing cylinder sits horizontally on the table and has an opening at one end into which chemicals are poured and emptied out. Pour in the developer, start the stopwatch, and roll the drum evenly back and forth on the table to begin developing. Cibachrome recommends a developing time of two minutes, but 2-1/2 minutes will result in better contrast for astrophotography with very little color shift. Fifteen seconds before the 2-1/2 minutes have elapsed, begin draining out the developer into the sink and continue draining for the remaining time. Place the drum on the table, pour in the bleach, and roll the drum again. Bleach time is four minutes. Drain the bleach into a separate container (you must neutralize it later before disposal; this is done for ecological reasons with the neutralizing chemicals provided). Pour in the fixer, roll for three minutes, and drain. Open the drum and allow water (at 75 degrees Fahrenheit) to run into the open end for three minutes to thoroughly wash the print of any traces of chemical. Remove the print, squeegee off excess water, blow dry with a hair dryer for about five minutes (a nice advantage of resin coated paper), and you have your print!

Now you must check the test print for two things: image density and color balance. Image density is easily determined by looking at the four exposures. A lot depends on whether the slide was over- or underexposed, and whether the subject you're dealing with is a faint wisp of nebulosity or a brilliant globular cluster. One of the test shots will look about right to you — not too burned in and overexposed, and not too faint and underexposed. Pick this lens setting for the actual print.

Next you come to the adjustment of the color balance. Here is where the real beauty of the Cibachrome process comes in. First of all, things are seldom so bad that everything on the slide, including the Orion nebula, is totally green or purple. What we are usually dealing with are more subtle examples of color correction: The subject looks pretty good but the background is slightly greenish or pinkish. Your Lagoon nebula could stand a little more red in it. Personal tastes will come into play. Some will like the Lagoon a blazing, vivid red, while others will prefer more moderate pastel shades.

The Cibachrome color print manual will be useful in learning how to judge color. It shows quite clearly the process used to correct color balance. You will be using three color filters: yellow (Y), cyan (C), and magenta (M). If your print looks too blue, you either subtract blue (M and C), or add yellow. If it looks too red, subtract red (Y and M) or add cyan. If too yellow, subtract Y or add blue (M and C). If too magenta, subtract M or add green (Y and C). If too cyan, subtract C or add red (Y and M). If too green, subtract green (Y and C) or add magenta.

A couple of points are well worth remembering here. First, adding or subtracting filters will increase or decrease exposure time at the enlarger. The table in the color print manual is invaluable for adjusting for this change. It shows the percent increase or decrease of exposure time depending on how much filtration is added or subtracted.

Also, use as few filters as necessary. All three colors (C, Y and M together) produce neutral density, and all this does is unnecessarily increase exposure time. The manual tells you how to figure out the minimum filter pack. You'll probably scratch your head a few times, but then it'll become clear to you!

After choosing the proper filtration (or possibly no filtration), go back and repeat the exposure and developing process, this time using a whole sheet of 8 x 10 paper with the selected lens opening and filtration. The result should be a beautiful color photograph of your subject and numerous pinpoint star images.

So you see, color printing is not that difficult at all. If you've been successful at black and white, color can be just as easy using the proper films and chemicals. Once having mastered the basic techniques, you'll be ready to experiment on your own for more sophisticated results. And when your friends come over and ask what observatory telescope took the beautiful color shots adorning your walls, you can enjoy their expressions of shock and disbelief when you point to yourself and your own modest six or eight inch telescope.

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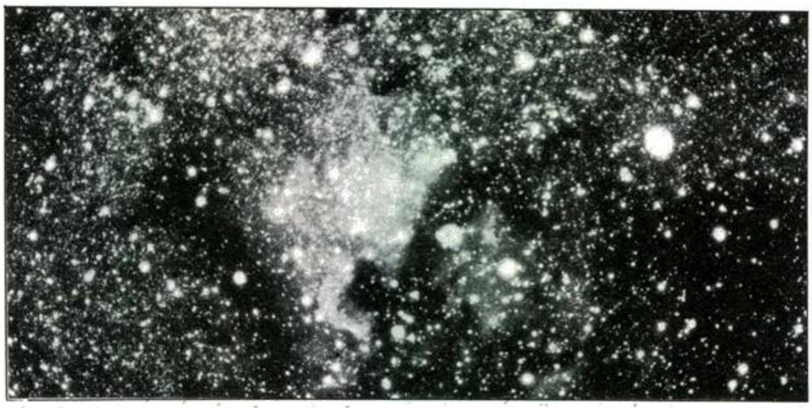

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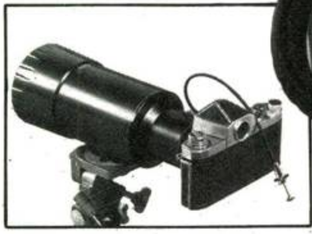

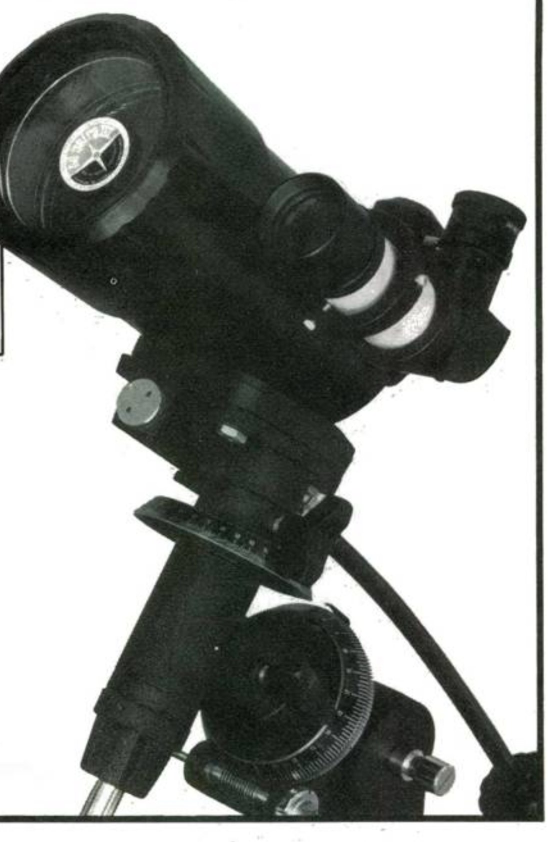

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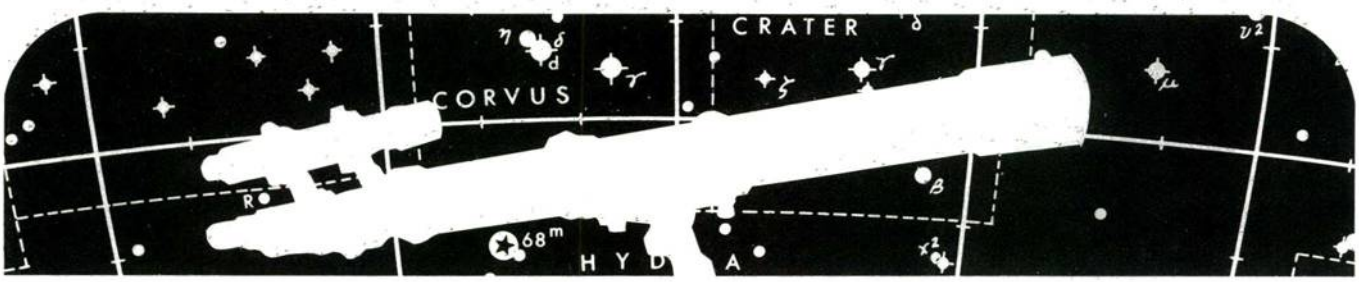


Celestial Software

Part 4: How to Calculate Horizon Coordinates

by

Robert Burnham

One of the more vexing practical problems in observing a celestial object is knowing beforehand how high and in what direction to look at some given time and date. Suppose there's to be a lunar eclipse and you'd like to take a series of pretty pictures of it, neatly framed by the church steeple and the old oak tree. Can you do it? How high will Venus get on the date of maximum brightness? Will the date of greatest elongation of Mercury coincide with its maximum elevation over your horizon?

The preparations are simple: You'll need a calculator that does trigonometric functions (sine, cosine and tangent, and their inverses), or a set of trig tables and a four function machine.

Basically it's a two step process; the first requires one computation, and the second, two. In outline, you have to calculate your local sidereal time (LST) for the date and time of interest in order to derive the object's hour angle. Armed with the hour angle and two other numbers (your latitude and the object's declination), you can launch into the altitude-azimuth calculations. Don't worry about the numbers; just follow the steps one-by-one, and you won't get lost! We've worked through an example so you can check your understanding as you go.

Local sidereal time is necessary because LST minus right ascension (RA) gives hour angle (HA), a vital ingredient of the formulas that follow. To get your LST for any day in the year (and time of day), use the following formula:

$$\mathrm{LST} = K + 0.0657\,N + 1.0027\,T - (L/15)$$

The symbols mean:

K = a constant with a different value for every year.

N = the number of the day in the year.

T = the Universal Time (UT) of the instant in question.

L = your longitude (in decimal degrees).

The values K has for the next few years are given below:

1978: 6.6204
1980: 6.5885
1979: 6.6044
1981: 6.6383

The number of the day in the year is derived by adding the day of the month to the month-number given below for the month in question:

Jan.	0	Jul.	181
Feb.	31	Aug.	212
Mar.	59	Sep.	243
Apr.	90	Oct.	273
May	120	Nov.	304
Jun.	151	Dec.	334

If the year is a leap year, add 1 to the day numbers for all dates after February. For example, Dec. 26, 1978 is day number 360, because 334 + 26 = 360. In 1980, which is a leap year, the same date would be 361.

Now, suppose you live in Milwaukee, Wisc. and you want to know the LST at 5:00 a.m. CST on Dec. 26 this year. The day number is 360, as worked out above; the UT of the moment of interest is 11:00 (because UT = CST + 6 hours), and Milwaukee's longitude is 87.9 degrees west of Greenwich. Dividing 87.9 by 15 gives the result 5.9. If we go back to the formula with this year's value for K and plug in the numbers, it sets up like this:

$$\mathrm{LST} = 6.6204 + 0.0657(360) + 1.0027(11) - 5.9$$

Photograph by Russ D. Holzer

Performing the indicated multiplications and additions (remember to multiply first!), you get LST = 35.4 hours, which looks silly! Because the number has come out greater than 24, just subtract 24 hours, and you'll have the proper result: LST = 11.4 hours.

(The formula piles up the corrections over the year and sometimes you'll get a result over 24 hours. Don't panic; just subtract as shown above!)

All right, you've got your LST — what's next? Well, to start on the altitude-azimuth computation, dig out three numbers: your *latitude* (if you don't know it, call your public library); the object's *declination* and its right ascension (RA). The declination and right ascension will be in Planet Finder, the **Nautical Almanac**, or a star atlas, catalog, or the like. The third number is the *hour angle* (HA) which is simply LST - RA.

In the example we're working on, Milwaukee's latitude is +43.1 degrees; the declination of the object (the moon, let's say) is -13.3 degrees, and its RA is 15.2 hours at the time of interest. The HA is -3.8 hours found by subtracting 15.2 hours (RA) from 11.4 hours (LST). Because calculators work in degrees, and because all other values in the altitude-azimuth calculations are in degrees, convert the HA into degrees by multiplying by 15: -3.8 hours x 15 = -57 degrees. In the example, we've rounded off to one or two decimal places; your machine will give you more, but the difference caused by using the full number of digits provided is insignificant.

Write three numbers (latitude, declination and hour angle) on a piece of paper, and you're ready to start crunching out the numbers! The formulas to use are as follows:

Altitude = arcsin (sin d sin L + cos d cos L cos HA),

and:

Azimuth = arccos [(sin d - sin L sin E)/(cos L cos E)]

The symbols mean:

d = declination of object
L = latitude of observing site
HA = hour angle
E = altitude, as calculated by the first equation.
arc- = the inverse of the trig function named.

Remember that all these figures must be in decimal degrees. If your machine doesn't provide a conversion for you, you can get it by rounding the number of seconds to the nearest minute, and then dividing the number of minutes by 60. Next, add the result to the number of degrees and you have decimal degrees!

(You won't get lost if you proceed *slowly* and *carefully*, writing down intermediate values as you go. This is a safety precaution you can discard as you gain practice.)

Now, if you put the values of the three numbers into the first equation and perform the trig functions, it looks like this:

Altitude = arcsin (-0.23 x 0.68) + (0.97 x 0.73 x 0.54)

Doing the arithmetic, you get:

Altitude = arcsin (0.23), or 13.29 degrees. (This becomes the value of E for use in the azimuth equation.)

The second formula works out like this:

Azimuth = arccos [-0.23 - (0.68 x 0.23)]/(0.73 x 0.97)

which reduces to:

Azimuth = arccos (-0.54) or 123 degrees.

And that's your result! The moon will be about 13 degrees high in the east southeast. (Venus will also be there, since this is the date and time for its occultation!)

There's only one little catch in the azimuth calculation: The value derived in the end is the azimuth only if the hour angle is *negative*, (that is, when the object is *east* of the meridian). If the hour angle is positive, you must subtract the "azimuth" value from 360 to get the real azimuth. See what happens in the next example.

We're still in Milwaukee and the date and time are the same. How high will Jupiter be and where in azimuth? The LST is as before; Jupiter's RA is 8.67 hours, its declination +18.92 degrees. Working out the hour angle, we get 11.4 - 8.67 = 2.73 hours, or 40.95 degrees.

Formula 1 now looks like this:

Altitude = arcsin (0.32 x 0.68) + (0.95 x 0.73 x 0.76)

which works out to:

Altitude = arcsin (0.74), or 48.13 degrees.

Keeping this value as E for formula 2 and working the trig, we get:

Azimuth = arccos [0.32 - (0.68 x 0.74)]/(0.73 x 0.67)

simplifying:

Azimuth = arccos (-0.37), or 112 degrees.

In this example, because the hour angle is positive, you subtract the "azimuth" derived above from 360 and get a correct azimuth of 248 degrees, some 22 degrees south of due west. Jupiter will be about 48 degrees high in the west southwest.

Sometimes all you want to know is the point on the horizon where a celestial object will rise or set. If so, the problem becomes very simple: All you need to know are your latitude and the object's declination. The formula is: Angle = arcsin (sin d / cos L), and the symbols are as used before. What comes out of the calculation is the angle north (if +) or south (if -) of due east (for a rising object) or due west (for a setting one).

For example, if the sun on Dec. 22 this year has a declination of -23.44 degrees, what's the azimuth of its rise as seen from Milwaukee? Putting in the proper values and doing the trig:

Angle = arcsin (-0.40/0.73)

which works to:

Angle = arcsin (-0.55), or -33.23 degrees.

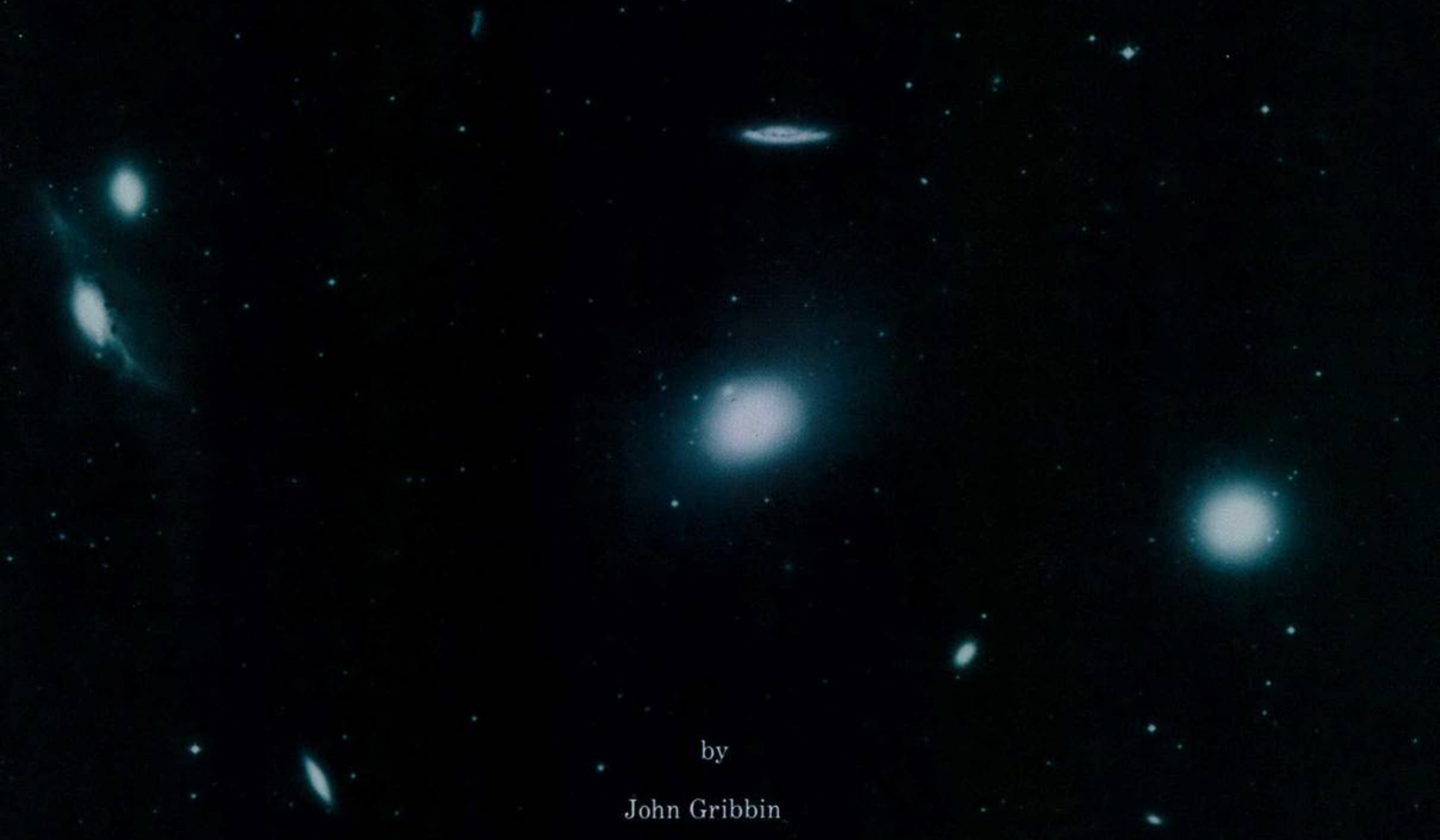
This means the sun will rise 33.23 degrees south of east or at an azimuth of 123.23 degrees.

We hope that you'll find many uses for these equations. After all, we have space to prepare altitude-azimuth diagrams only for one latitude, which is ususally 40 degrees north, giving an "average" diagram. Armed with the above formulas, though, you can calculate your own personalized diagrams for your specific needs!

Do We Live in

Strewn across the north central region of Virgo are the members of the Virgo cluster of galaxies, the most plentiful such cluster known. Throughout this rich assemblage of galaxies scientists have found a wide assortment of galactic forms, some appearing quiescent, others wracked with upheavals and turbulence. As yet no one knows why this should be. Perhaps all galaxies at one time in their lives are disrupted, and we're seeing a cross section of the whole population. Photograph copyright © 1978 by U. K. Schmidt Telescope Unit.

an Exploding Galaxy?

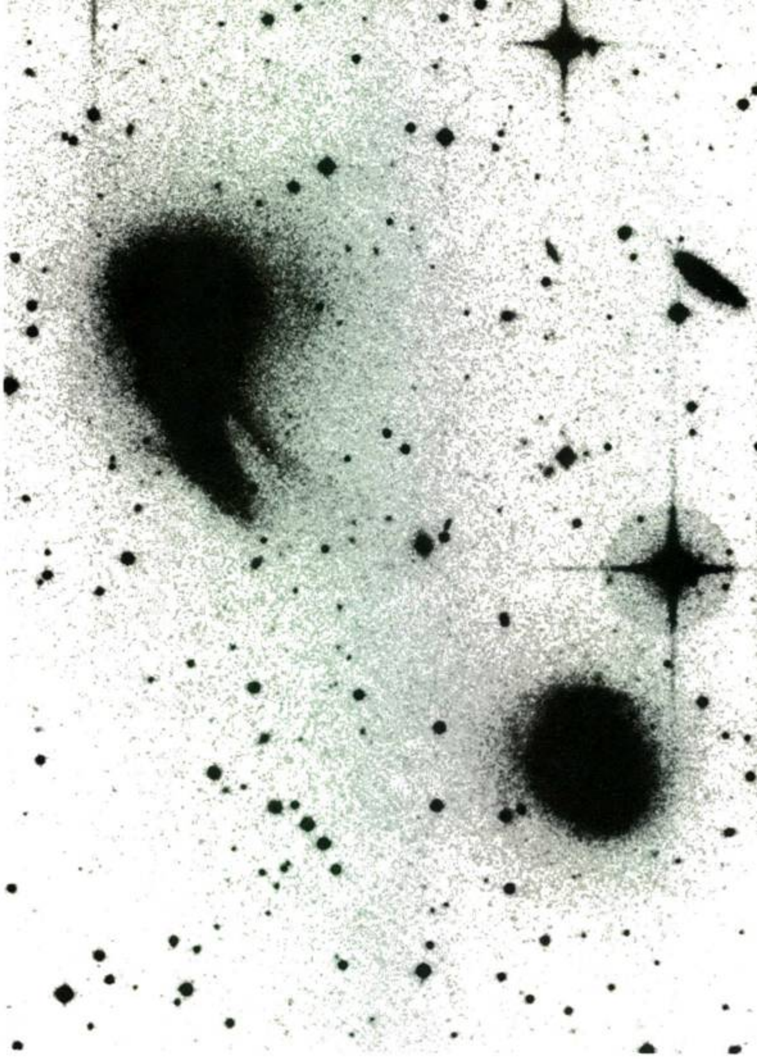


by

John Gribbin

Not long ago it seemed that observational astronomy had produced a fairly complete picture of our Milky Way galaxy: an orderly system in which stars wheel around the nucleus in more or less circular orbits, forming — along with gas and dust — the beautiful spiral pattern common to many galaxies through the passage of a traveling density wave. But this picture has begun to look a little frayed around the edges, as ever better observations have provided more and more information about the structure of the galaxy and, in particular, about the nucleus itself.

It is now clear that there is a vast source of energy at the galactic nucleus, comparable to the sources of energy which power the explosions in Seyfert galaxies, although there is no suggestion



Tidal interactions between these two faint galaxies has pulled matter out into space, earning the top one the nickname of the Fly's Wing galaxy. Or has the core of this galaxy erupted, sending a wave of material out from the center? Can such eruptions happen, and how common are they? Photograph copyright © 1978 by U. K. Schmidt Telescope Unit.

that our galaxy is a Seyfert "at present". Infrared, radio, x-rays and gamma rays are all now being used to probe in more detail the murky region of the galactic center. There astronomers find streams of gas ejected from the plane of the galaxy, a circular ring of cool gas clouds right around the nucleus, and outward moving (or expanding) features both on "our" side of the nucleus and across on the other side of the galaxy.

But in all this study a key problem has remained. No one has been totally certain that all the activity being observed in the direction of the galactic center (in the constellation Sagittarius) really was the nucleus itself. The Doppler shift of the spectral lines from the radio source at the center shows that it is moving away from us at 40km per second. Conventional wisdom has it that the sun and solar system are in a circular orbit around the galactic nucleus, so that no such recessional Doppler shift should be seen.

And there are lesser, but still worrying, difficulties about other motions in the galaxy. Take the "expanding" features, for example. These seem to be clouds following the shape of spiral arms, but moving outward from the center of the galaxy. One, between us and the sun, is moving our way at 55km per second. This so-called "three kiloparsec arm", named for its distance from the galactic center, is a prominent source of 21cm hydrogen radiation. At the same distance beyond the galactic center is another similar feature, making for a pleasing symmetry about the galactic center except for one thing: That arm is moving away from us *not* at 55km per second (as we might expect if the velocities were symmetrical about the nucleus), but at 135km per second.

Perhaps our galaxy is lopsided, but the best maps (mostly made with the aid of 21cm observations) show a classic symmetrical disk, like other Sa or Sb galaxies. Can it be a coincidence that two features, moving outward at very different velocities, happen to lie symmetrically about the nucleus just now?

Their average velocity (taking into account the opposite direction of the velocities — +135km per second for one feature and -55km per second for the other) is 40km per second, the same as the velocity of the central feature in Sagittarius! This hardly looks like a coincidence, for if the outward moving gas clouds are symmetrical both in space and in velocity about the nuclear radio source, that must make it an excellent candidate for the true center of our galaxy. But if that interpretation is correct, it means that *we* are not at rest relative to the nucleus! Certainly the solar system is in orbit around the galactic center; but in addition, we too are moving outward from the nucleus with a velocity of 40km per second.

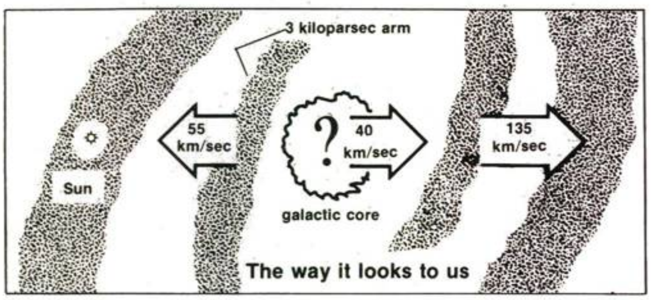
Because the solar system could hardly be special regarding its overall velocity, what we are really saying is that the whole group of stars which constitutes the Local Standard of Rest (LSR) is moving outward as if expelled from the inner regions of the galaxy in some long ago explosion. Although this runs counter to a basic tenet of the theory of the structure of our galaxy, it does *not* run counter to any observations. At present, observations are not yet precise enough to say with certainty whether the orbit of the solar system is simply circular or circular with an outward velocity imposed on it.

Starting from this observational base, Dr. Victor Clube of the Royal Observatory in Edinburgh, Scotland, has set out over the past few years to look at what the existence of such noncircular motions, if real, might mean for the structure and history of our galaxy.

The exciting possibility of linking such changes with the violent changes observed to be going on in many galaxies — even Quasistellar Objects — has encouraged Clube to follow up the implications in detail. To anyone familiar with the more usual ideas of the galaxy as a stable system, the results are both exciting and uncomfortable! However, considering all the evidence for various explosive events in the universe, overall it is an exciting and uncomfortable place to live!

Hints that the LSR (that is, the other stars in the sun's vicinity) is in fact moving outward from the galactic center are supported by a surprising amount of observational evidence, once the incentive to seek it has been provided. Nearby dwarf-M stars, for example, have a mean outward motion of around 30km per second.

On a rather larger scale, the correction that Clube suggested should be applied to the true standard of rest for the galactic nucleus helps astronomers puzzling over the relationship between our galaxy and M-31: With the assumption that the solar system is at rest relative to the nucleus (except for the orbital motion), it has proved difficult to establish whether or not M-31 and our galaxy orbit one another. Subtract our 40km per second from the equations, however, and the situation is resolved; the relative velocities then fall comfortably in the range for bound orbits.



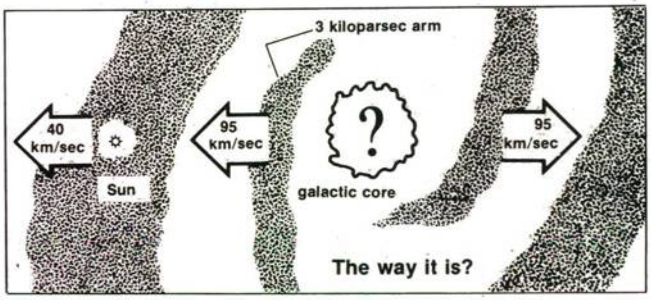
Overall, Clube has gathered a wealth of evidence supporting the view that most of the gas and young stars (less than 500 million years old) in the galaxy are moving outward with velocities inversely correlated with distance outward from the nucleus. The inner regions of the galaxy are moving more rapidly, and will overtake some of the outer features. Such a phenomenon could be produced by an asymmetry in the structure of our galaxy, if our galaxy were a barred spiral. But there is no other evidence that our galaxy is a barred spiral. As long as we can only study in detail 1/4 the galactic disk — a 90 degree "pie slice" centered on a line from the sun to the nucleus — we can't be sure.

However, *assuming* symmetry in the distribution of velocities, Clube came up with an intriguing model: a galaxy wracked by repetitive, large scale, axially symmetric expansions. In this situation, the present spiral pattern cannot last for long. So unless we live at a very privileged time in the history of the galaxy, it suggests that such events are repetitive. It turns out that the characteristic timescale for the radial disturbance must be about 10^8 years. Therefore, the galaxy will soon "recover" from the present convulsion, and in due course go through a similar transformation. Each explosion must *temporarily* generate the structure of spiral arms that we now see, but in turn each spiral pattern dissipates as the turmoil works its way out of the system.

This picture is indeed far from the present standard view of arms as a spiral density wave phenomenon. Clube's provisional model sees spiral arms produced in the form of cold material ejected from the central region of the galaxy. Where might it come from? Perhaps from the fission of some supermassive, spinning object, the true galactic core. At present, overall distribution of gas is consistent with two bursts in the recent past. The -55km per second and +135km per second features appear to lead the second burst; just ahead of these features lies a peak concentration of ionized interstellar hydrogen, suggesting that the second burst is overrunning and heating lagging material from the first burst.

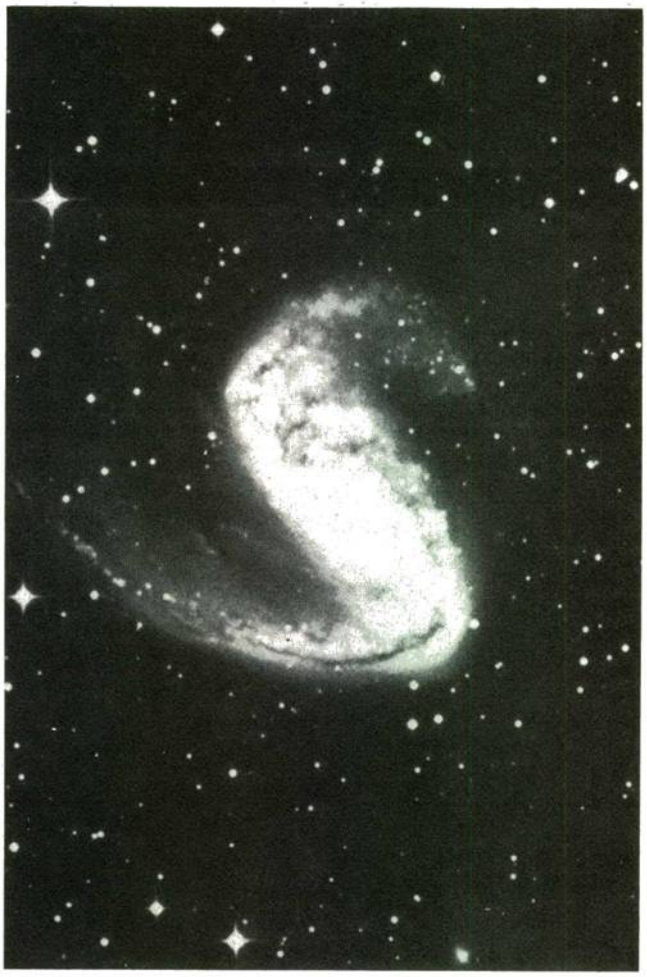
As Clube said, "That the model is self-consistent and even plausible may in the end have no greater physical significance than the fact that the moon appears to be the same size as the sun!" Even though everything seems to hang together, at least one key test is needed before the model gains respectability.

Failing a direct way to measure the velocity of the compact source at the nucleus, Clube has pointed out that the developing study of interstellar clouds by their carbon monoxide millimeter-wave radio emission (at 2.6mm) may hold the key. This emission is so weak in directions outward from the solar system that it should provide an ideal unambiguous test for unraveling signals from the galactic center direction. The technical ability to make the critical test already exists. It needs only to be applied (from southern hemisphere radio observatories), as it surely will now that Clube's model has increased interest in theories of the nature of our galaxy.



Meanwhile, if we throw caution to the winds and accept the notion of recurring waves of outward motion rippling through the galaxy every few hundred million years, what can we say about conditions at the core? How might the waves be generated, and what effects might we expect on Earth, subjected to repeated buffetings in its 4-1/2 billion year history?

Looking back from the present to the time of the lastest explosion (about 4 x 10^7 years ago), the galaxy must have been much more compact — no



Above is NGC-2442, a spiral galaxy in the southern constellation Volans, the flying fish. Clearly seen are the two arms sweeping out from the central core, which both appear to have highly turbulent motions. Are the forces driving these motions coming from within, or is there another galaxy behind NGC-2442 causing the disturbances? Photograph copyright© 1978 by U. K. Schmidt Telescope Unit.

bigger than half its present size. Furthermore, the energy involved in the outward movement of the spiral arms near the center of our galaxy must be about the same as that observed in the explosion of a Seyfert galaxy. It makes some sense to think of the expanding spiral structure as created by that kind of explosion. The model goes further: It suggests our galaxy has *repeatedly* undergone Seyfertlike explosions — and if our galaxy can do it, why not all of them?

Looking at the range of energies seen in various exploding galaxies, the outcomes of such events might range from large, extensive spiral arms (like those in the outer parts of our galaxy) to the smaller disturbances now seen nearer the center. "Spiral arms are simply massive ejecta from the nuclear regions of galaxies...stretched out by differential rotation," Clube said. Even bigger explosions might blast material free of a galaxy, producing a double lobed structure like that of so many radio sources, or jets like those seen in some quasars.

Observers such as Prof. Halton Arp, Soviet Academician V. A. Ambartsumian, and theorist Sir Fred Hoyle are among those who have argued at one time or another that "supermasses" in galactic cores might break up, producing a wide range of observed explosive phenomena, including the fission of a galaxy into two or the ejection of a compact "quasar" from the nucleus of a galaxy. All these ideas may now receive more attention in the light of Clube's work. But the key question remains: How does a supermassive core explode and/or fission?

There are two basic possibilities. Either the phenomenon can be tackled by conventional physics, perhaps pushed to the limit in a supermassive black hole, or perhaps (as Hoyle has long argued) there is a need for a "new physics" to deal with supermassive concentrations of matter. Whatever it is that goes on in the core appears capable first of squeezing the whole galaxy, and then of blasting material outward in a violent "rebound" — an explosion of colossal dimensions.

Hints of a link — however tenuous — with events in the geological history of Earth may sway some doubters over to Clube's point of view. Upheavals on Earth appearing to coincide with the deaths of many species of flora and fauna occurred 560, 390 and 225 million years ago, and most recently about 60 million years ago when the dinosaurs were wiped out. The span between these unexplained disasters is more or less correct for the timescale of a few hundred million years between successive major core explosions. A catastrophe powerful enough to pull the solar system in toward the galactic center, and then bombard it with material as it swayed back out into a more distant orbit, surely would have left some traces! Look at it this way: If the geological record showed that Earth had had a placid history for the past billion years, it would be very hard to reconcile with the possibility that the galaxy had a violent history. Evidence for a violent history of planet Earth doesn't *prove* the galaxy underwent convulsions, but something certainly did shake up the solar system, and more than once!

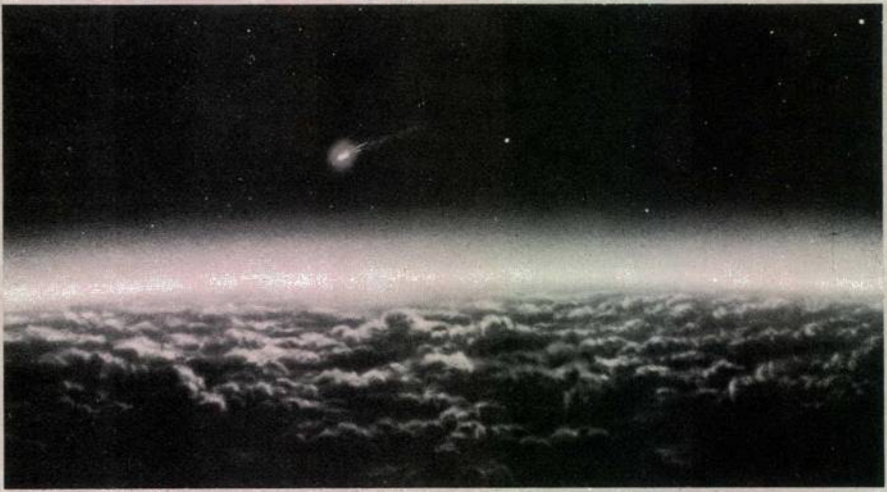
Where does this leave Clube's model today? It's certainly out of the mainstream of modern thought about the behavior of galaxies. But it's respectable enough to justify some efforts to check on whether the LSR really is moving out at 40km per second from the galactic center. This may be a controversial issue like the steady state theory — an issue that encourages observations which, in the end, prove the model wrong, but which add greatly to our understanding of the universe. Or, just maybe, those observations will really upset the applecart! Hold on to your hats — and watch out for news from the southern hemisphere radio observatories.

Dr. John Gribbin is a member of the Science Policy Research Unit at the University of Sussex, England. He has written several popular books on astronomy and earth sciences, including **Our Changing Planet** *(Crowell).*

ASTRO-NEWS

Latest News From the World of Astronomy

Rendezvous With Venus



The Pioneer Venus multiprobe bus burns up in Venus' upper atmosphere in this artist's conception. After launching its four probes 20 days out from Venus, the bus is retargeted to enter the atmosphere 85 minutes after entry of the last probe. The bus becomes a probe itself, making high upper atmosphere composition measurements before it starts to burn up around 75 miles from the surface. NASA artwork.

The curtain will open on a new act in the drama of our exploration of Venus in early December with a *ménage á trois* rendezvous involving the United States, Russia and the veiled planet. This latest act promises to be the most exciting yet, perhaps the climax of the whole drama, as a large number of probes return an unprecedented amount of new information about Earth's sister planet.

The U. S. is represented by two probes, each a unique spacecraft with entirely different missions. One will orbit the planet, seeking data at all levels — from the ionosphere to the surface, to the deep interior. The other will separate into five sections, each to probe different regions of the atmosphere during a single hour of glory.

In mid-September, the Soviets launched two Venus probes of their own. The probes are each expected to drop a landing capsule which will probably try to endure conditions of the Venusian surface for up to six hours while conducting as yet unrevealed experiments. The main spacecraft will flyby and not orbit the planet.

Like the exotic performer in the legendary "Dance of the Seven Veils", the mysterious planet Venus has been dropping her curtains of mystery one by one. The namesake of the goddess of beauty has given up her concealing veils under the urgent prodding of robot visitors and radar pulses from Earth. But new mysteries have taken the place of the old.

The history of the exploration of Venus falls into several stages. The first veil fell in the early 1960s when Mariner 2 showed that the high temperature readings were really from the planet's surface, and radar probing revealed that the planet spins backwards very slowly. New atmospheric discoveries by Mariner 5 and Venera 4 in 1967 could be seen as the parting of another veil.

The series of Soviet atmospheric probes of 1969-1972 confirmed the high temperatures and pressures by direct measurement. In the early 1970's radar revealed shallow craters and gentle ranges of hills. Then Mariner 10's ultraviolet cameras confirmed (but could not explain) strange activity in the planet's upper atmosphere. Finally, the Soviet Venus landers of 1975 and United States radar probing measured the nature of the surface.

Venus remains a tempting target, for despite the great increase in human knowledge about the veiled planet, basic questions remain. Its slow retrograde spin and suggestive synchronization with Earth is unexplained (and perhaps unexplainable). Surface activity, including volcanism, cratering and possibly continental drift, needs to be charted. The atmospheric constituents, levels and dynamics remain puzzling, as each new discovery raises additional questions. Perhaps most important for the concept of the likelihood of any Earthlike planets existing elsewhere in the galaxy, did Venus ever have oceans, and if so, why did they disappear?

Pioneer Venus 1 and 2 (nobody knows why they weren't just called Pioneers 12 and 13) will address these and other unanswered questions. This current project, if successful, will likely double our knowledge of Venus. It should also pinpoint target areas worthy of following probes in the 1980s.

The most spectacular day in the dual mission will be Dec. 9 (five days after the orbiting PV-1 takes up its duty station), when the "invasion fleet" of PV-2 arrives (sort of a peaceful Multiple Independently-targeted Re-entry Vehicle, or MIRV). One large probe and three identical small probes will have been jettisoned from the "bus" carrier a few weeks earlier, each on a separate trajectory heading for northern, dayside and nightside impacts. To conserve battery power, the fleet will be on radio silence until a half hour before entry.

Venus *continued on page 60*

X-Ray Astronomy Expanding

The second spacecraft in the High Energy Astronomical Observatory (HEAO) series was scheduled for launch on Nov. 17. If successful, it will be known as HEAO-2.

Its mission is to continue and expand the observations of HEAO-1, launched Aug. 12, 1977. A third HEAO satellite is scheduled for 1979.

The program is designed to enable astronomical observations in the high energy portion of the electromagnetic spectrum, spanning the range from soft x-rays through hard (higher energy) x-rays to soft gamma rays.

Already, HEAO-1 has painted an entirely new celestial map for astronomers and astrophysicists. Erase, for a moment, the map you know and replace its pitch black background with a dull glow. Scatter across that glow a thousand pinpoints of brilliance, some steady, some blinking rapidly, and a few that blind for moments and then fade away for months or years.

"X-ray sources barely visible in older studies stand out clearly in HEAO-1 data," said Dr. Noel Hinners, NASA's associate administrator for space science. "The faintest sources are one million times weaker than the first x-ray star discovered 15 years ago."

HEAO-1 did not actually discover x-ray astronomy, but it has been comparable to giving Galileo the use of a 120 inch telescope! The satellite observatory has worked so well that its life was extended from the original six month scan to at least 18 months.

We know now that all stars emit energy throughout the electromagnetic spectrum, from long radio waves to short x-rays and gamma rays, including light. But until 1964 it was thought that only the sun, because of its closeness, could be seen in x-rays. That year a sounding rocket experiment showed that the Crab nebula was emitting 10,000 times as much energy in the form of x-rays as it was in radio! With that one flight, a new field of astronomy was born.

Basic satellites soon followed, the most famous of which was Uhuru (a Swahili word meaning "freedom"), launched in 1970 as the first of the small astronomy satellite series. As a result, over 300 x-ray sources were identified and catalogued.

HEAO-1 carries four survey experiments designed to build up a more detailed high energy map of the sky. They cover the energy range from 150 electron volts (150 eV) to 10 million electron volts (10 MeV). Light waves occur in the range of tens of electron volts. It takes about six months to scan the entire sky, so the new 18 month mission will cover the sky three times.

A pioneer in the field, Dr. Herbert L. Friedman of the Naval Research Laboratory, said, "The various instruments on the spacecraft are, I think, a very good mix to do a survey of this entire spectral range." Friedman added that HEAO-1 should increase the number of confirmed x-ray sources from 339 to at least 1,000. "The principal objective of this mission is to cover the sky uniformly, to give us a complete map as a new baseline for all future experiments in high energy astronomy."

Dr. Harold Gursky of the Smithsonian Astrophysical Observatory said, "Whenever you look at an object in different wavelengths (energies) with different machines, you are seeing different physics. It's extremely important to look at the whole range of wavelengths to get the whole picture."

Each of the four experiments aboard HEAO-1 has a specific mission, and each has already returned significant findings:

Experiment A-1 is a large area x-ray survey covering the 0.15 to 20 thousand electron volt (keV) range of the spectrum. What it lacks in pointing precision, its 42 square feet of aperture makes up in sensitivity.

Results: While it's hard to point to anything as a fundamental discovery, a new candidate for a black hole has been tentatively identified.

Experiment A-2 is observation of cosmic x-rays in the 0.2 to 60 keV range. Project investigators are Dr. Elihu Boldt of Goddard Space Flight Center, and Dr. Gordon Garmire of the California Institute of Technology.

Results: According to Boldt, experiment A-2 has detected radiation coming from an intergalactic source heated to 500 million degrees Kelvin.

"If this is due to a gas," Boldt explained, "it probably represents more than any other form so far observed in the universe." This would mean that the universe will eventually stop expanding due to a strong mutual gravitational attraction, and begin to collapse instead. But he added, "That depends on how clumpy this gas is." (See Astro-News, May 1978 for further information.)

Boldt said that unexpected x-ray emissions were found coming from the strange N-class galaxies which have compact nuclei.

"The biggest surprise is that these 'BL Lacerta' objects that are not clustered are almost all highly variable," he said. Their day-to-day variability and intensity indicates that such sources are smaller than our solar system and yet generate one billion times as much energy as the sun.

Garmire deals with the upper energy range of experiment A-2. Among the unusual things spotted in this range is that Alpha Centauri, the second closest star to our sun, is 10 times brighter in x-rays than the sun. And RS Canum Venaticorum is a very active flare star producing 10,000 times as much energy in x-rays as the sun does.

"It's quite a bit of energy for a star that's in a class not too much different from our own," Garmire said. He speculated that one reason may be extremely twisted magnetic fields and a surface area 100 times greater. Although only 14 such stars have been observed nearby, Garmire said there may be as many as one million in our galaxy alone.

Other unusual observations include a white dwarf, SS Cygni, with a shorter rotation period (1.89 seconds) than ever observed before.

Experiment A-3 utilizes a scanning modulation collimator to locate precisely the various x-ray sources so optical astronomers can study them. "This particular experiment is optimized to measure precisely where things are in the sky," said Gursky. "Because we are optimizing positions, we have not wound up with the most sensitive instrument."

Results: Although many of the sources examined by HEAO-1 were already known, their positions were known only with an error of a full degree, twice the apparent diameter of the full moon. So far, experiment A-3 has provided 150 locations to within 5 to 10 seconds of arc, about 1/200 the diameter of the full moon.

"The precision of HEAO A-3 positioning is good enough," said Dr. Hale Bradt of the Massachusetts Institute of Technology, the other project investigator on experiment A-3, "that invariably optical astronomers succeed in finding the star."

The most notable of these sightings was Nova Ophiuchi 1977. Its x-ray emissions were noted first by Ariel 5's all-sky sensors, but only a general area was determined. HEAO A-3 gave an accurate enough position that observers at the Anglo-Australian Observatory in Australia were able to photograph it on Sept. 8 before it faded away. HEAO A-3 also provided conclusive evidence that Markarian

HEAO *continued on next page*

Space Telescope Started

Grinding of the 94-1/2 inch (2.4m) primary mirror for the Space Telescope is underway, and critical work is starting on the design of guidance and electrical power systems.

However, a proposed $15 million cut in next year's budget would ultimately cost $25 million and delay the launch by six months, according to Space Telescope officials.

Dr. Noel Hinners, NASA associate administrator for space science, told the House of Representatives Space Subcommittee that the budget cut is "highly undesirable", and would cost more in the long run.

Hinners and William Keathley, telescope project manager at Marshall Space Flight Center, briefed subcommittee members on the $0.5 billion project. They said the mirror will take up to three years to make, so Perkin-Elmer Corp. has already started work. Polishing of the first of two 1,700 pound mirrors started in October. Perkin-Elmer is also working on two designs for the fine guidance sensor which must maintain an accuracy of 0.01 seconds of arc.

Because of the solar activity which has degraded Skylab's orbit, NASA is considering placing the telescope in a 370 mile high orbit instead of 215 to 320 miles. The first launch is set for December 1983. In 1988, the Shuttle will retrieve it for refitting with six new instruments and the second of the two mirrors.

Requests for proposals will be issued in 1980 for a contractor to operate the Space Telescope Institute, which would handle space operations.

NASA expects to use the Space Telescope through the end of this century. Although it is smaller than most Earthbound telescopes, it is expected to out-perform the largest because of its position above the atmosphere. Hinners said, "If the universe has a beginning, we should be able to see some objects as they were near the beginning of time."

2 New Galaxies In Local Group?

Two new dwarf irregular galaxies discovered by an international team of astronomers using the 1.2m United Kingdom Schmidt telescope in Australia are being considered as candidate members of our local group of galaxies. (About 25 members are already known, mostly dwarfs.) A similar dwarf galaxy in the local group was discovered last year from photographs taken with the same telescope (see Astro-News, February 1978). These discoveries confirm the suspicion that numerous unknown dwarf galaxies populate the local group, and probably all galaxy groups.

The two new local group candidates lie in the constellations Sagittarius and Sculptor. They are termed UKS 1927-177 and UKS 2323-326, from the telescope that discovered them (the UK Schmidt) and their approximate celestial coordinates. The galaxies appear very blue, indicative that they contain hot, young stars. Astronomers have suggested that the galaxies have recently undergone bursts of star formation.

Distance estimates based on the apparent magnitudes of their brightest stars indicate that the galaxies are approximately 3.6 million and 4.2 million light-years away respectively, compared with a distance of 2.2 million light-years for the Andromeda galaxy, a major member of the local group.

HEAO

continued from previous page

501, one of a class of peculiar galaxies which are strong ultraviolet emitters, is a strong x-ray source. HEAO experiment A-1 indicated this, but A-3 was needed to pin down the location.

Experiment A-4 is the detection of hard (high energy) x-rays and soft gamma rays (even higher in energy than hard x-rays). The project investigators are Dr. Laurence Peterson of the University of California and Dr. Walter Lewin of MIT.

Results: According to Peterson, "One of the things we've been able to confirm is that the galactic center region is a producer of gamma rays around 4.4 MeV," something which was only a prediction before HEAO-1. He has also been able to measure cosmic particle intensity through the x-rays produced when they collide with dust and gas. Little can be deduced, though, about the cosmic particles' origins because the x-rays do not show their paths, only their presence.

One remarkable result from A-4 is the confirmation that the magnetic field at the surface of a neutron star is billions of times stronger than Earth's. Lewin said this was observed as an emission line in the x-ray spectrum of 3U 0115+63 and an absorption line in Hercules X-1.

"Now we have a tool that is very nice for the surgeon to operate on the surface of a neutron star," Lewin explained. "It obviously opens up a whole new branch of astronomy."

The second HEAO satellite incorporates a 60cm x-ray telescope, and will return data in the form of pictures. Because x-rays cannot be handled as light is, a trick called grazing incidence will be used. This can be observed if you view a sheet of glass almost edge-on. At this angle the transparent glass becomes reflective like a mirror. The new HEAO telescope will function the same way, using cylinders of quartz glass coated with chrome and nickel to focus x-rays.

At the focus, a turntable will rotate four experiment packages under the incoming x-rays:

B-1, a three unit high resolution imager;

B-2, a crystal spectrometer;

B-3, an imaging proportional counter; and

B-4, a solidstate spectrometer.

A fifth experiment package is mounted outside the x-ray telescope:

B-5, a monitor proportional counter.

The x-ray images from the telescope will cover only the 0.2-4 keV range. The images, made up of squares of varying intensity, will have a resolution as good as 1-2 seconds of arc and fields of view up to a full degree. Point sources will still appear as such, but detailed studies will be possible of extended sources such as the Crab nebula.

The third and last HEAO satellite will carry experiments sensitive to the higher energy range not covered by the second — hard x-rays and gamma rays — and will be able to detect cosmic particle momentum and mass. It will scan in the same way as HEAO-1.

No missions are approved beyond the HEAO series, but NASA is studying an advanced x-ray astrophysics facility that would draw on HEAO and space telescope designs (see Astro-News, August 1978). Known as AXAF, this system would have a 120cm aperture and yield resolutions 10 times better than the best HEAO observations.

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Venus *continued from page 57*

The large probe will hit the atmosphere at more than 26,000 m.p.h. Its heat shield will absorb the tremendous thermal stresses, but the entire vehicle will be subjected to a momentary deceleration stress of more than 300 Gs (300 times the force of Earth's gravity).

Once past these hurdles, the probe will cast off its scorched heat shield and deploy a parachute for 17 minutes of slow descent. At that point, still almost 30 miles high, the parachute will be cut loose and the sphere will freely sink through the dense atmosphere. It should take another 40 minutes to reach the surface, at which point the nominal mission ends.

Survival of impact is not planned, and no special ground measurements are scheduled. But it would not be too surprising if one or more probes *did* live long enough to send additional data while being cooked and crushed on the surface.

The small probes will reach Venus about this same time, enduring decelerations between 200 and 600 Gs (depending on the angle of atmospheric entry). They keep their heat shields attached, and have no parachutes, falling freely all the way down. So dense is the atmosphere that the small probes will take about an hour for their plunge.

The "bus" spacecraft has no heat shield, but it carries instruments to "sniff" the ionosphere when it reaches Venus an hour after its four probes. The bus will burn up after several minutes of high altitude reconnaissance.

Atmospheric data is the main goal of all five parts of PV-2. Data returned previously has revealed the Venusian atmosphere to be more complex and fascinating than expected (see box). Pioneer's instruments have been designed with past experience in mind, and include a gas chromatograph, a mass spectrometer, an infrared radiometer (looking out through a diamond window), a nephelometer (or cloud sensor, which peers out of the titanium hull through two sapphire windows), a cloud particle sensor (using another sapphire window), and a solar flux radiometer (using five more sapphire windows). A thermometer is attached on the outside of the hull, and internal accelerometers will measure the resistence (and hence thickness) of the atmosphere at various levels.

The upper atmosphere of Venus is directly brushed by the solar winds, since there is no local magnetic field to ward off the solar charged particles (which are twice as intense as near Earth). There seem to be layers in this thin, low ionosphere.

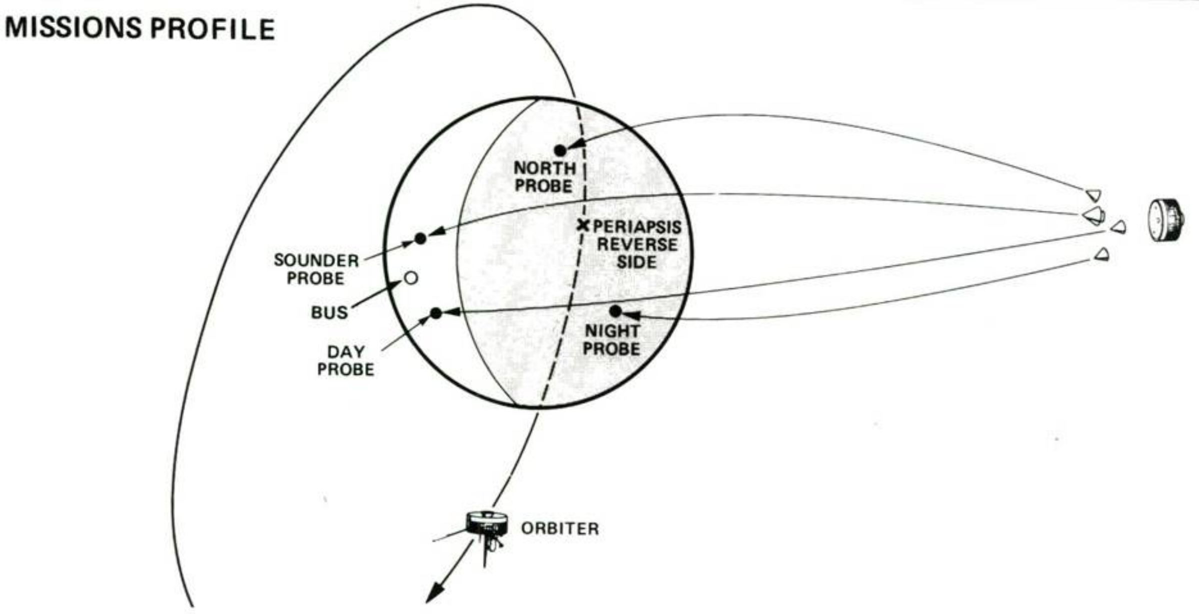
Below the ionosphere are more layers of haze and clouds, perhaps marked by temperature inversions. Ultraviolet photos from Mariner 10 showed black and white streaks circling the planet every four days. Scientists want to determine if this is a real transport rate or, as a minority of planetologists maintain, a shock wave propagation rate.

If the winds are real, what forces could be driving them? Whatever the movement of the markings turns out to be, why are any of the markings dark at all? They are not holes in the clouds, as you might assume by analogy with Earth cloud photos, but are evidently some material which changes form and reflectivity depending on some combination of as yet unknown factors.

Deeper within the Venusian clouds, scientists want to determine the composition of the various levels and how it changes with altitude. Just how much of the air really is carbon dioxide? The clouds, which are known to be made up of tiny droplets of something (possibly sulfuric acid), have been found by the Russians to have an internal visibility of about one mile. This makes them more like a blanket of thick urban smog than like a traditional Earth water cloud.

At a height of about 36 miles, the cloud layers break the atmospheric pressure and temperature too high to maintain whatever mechanism gave rise to the clouds at higher altitudes. Below this point, the air is clear, with a little dust. How much dust, and how dust can be generated at all when surface winds are so gentle, are other major questions.

Despite talk of a greenhouse effect (which is itself an implicit misunderstanding of the actual principles involved in greenhouse warmth in winter), scientists cannot — without knowledge of all the constituents (including trace constituents) of the atmosphere — really ascertain the origin and stability of the high Venusian temperatures (about 900 degrees Fahrenheit, fairly uniform all over the planet). Chemical analyses



This diagram shows the atmospheric entry points of the various probes as well as the orbit of Pioneer Venus 1. Sites and orbital orientation are as seen from Earth on Dec. 9, the date of multiprobe entry. The atmosphere will be sampled at a number of different sites, including both the day and night sides of the planet, to enable scientists to build up a large scale atmospheric profile. None of the probes is expected to survive surface impact, but the orbiter should return data for at least one complete rotation of Venus (243 Earth days). NASA diagram.

and temperature profiles of the atmosphere are crucial to this question.

The problem of the hypothetical Venusian water ocean is also important. If theories about Earth's origin are correct, Venus, too, should have outgassed great quantities of water from its volcanos (the amounts of carbon dioxide on both planets are about the same). Although it's easy to say these oceans would have evaporated and then would have had their molecules dissociated by sunlight into hydrogen (which would escape into space) and oxygen (which would become locked into a rusty regolith rock layer), the actual mechanisms of this process are not that simple. A layer of rocky debris literally miles in thickness would have to have been slowly turned over and exposed to the free oxygen, via some sort of erosive processes which cannot be imagined today, in order to absorb all the oxygen which would have been left over from the boiled oceans.

If there were oceans, some trace of them would remain in the atmosphere. Alternately, if there never were any Venusian oceans (and the Pioneer Venus instruments should be able to establish this, if true), the origin of Earth's own oceans would become a mystery.

A collision between some large asteroid and the proto-Earth may have allowed continental drift to begin, by stripping away a large fraction of the granite crust and giving enough slack for the internal tectonic forces to push the great plates around. The question of continental drift on Venus is relevant here, and some answers may also be provided by the other U. S. Venus probe, the orbiter.

The wobbles and shifts of the orbit of PV-1 will allow determination of mass distribution and density differentiation within the planet itself, just as geodetic measurements were made by analysis of satellites of Earth, the moon and Mars. Two Russian probes sent back signals from Venusian orbit in 1975-1976, but Soviet radio equipment was not sensitive enough to interpret any wobbles.

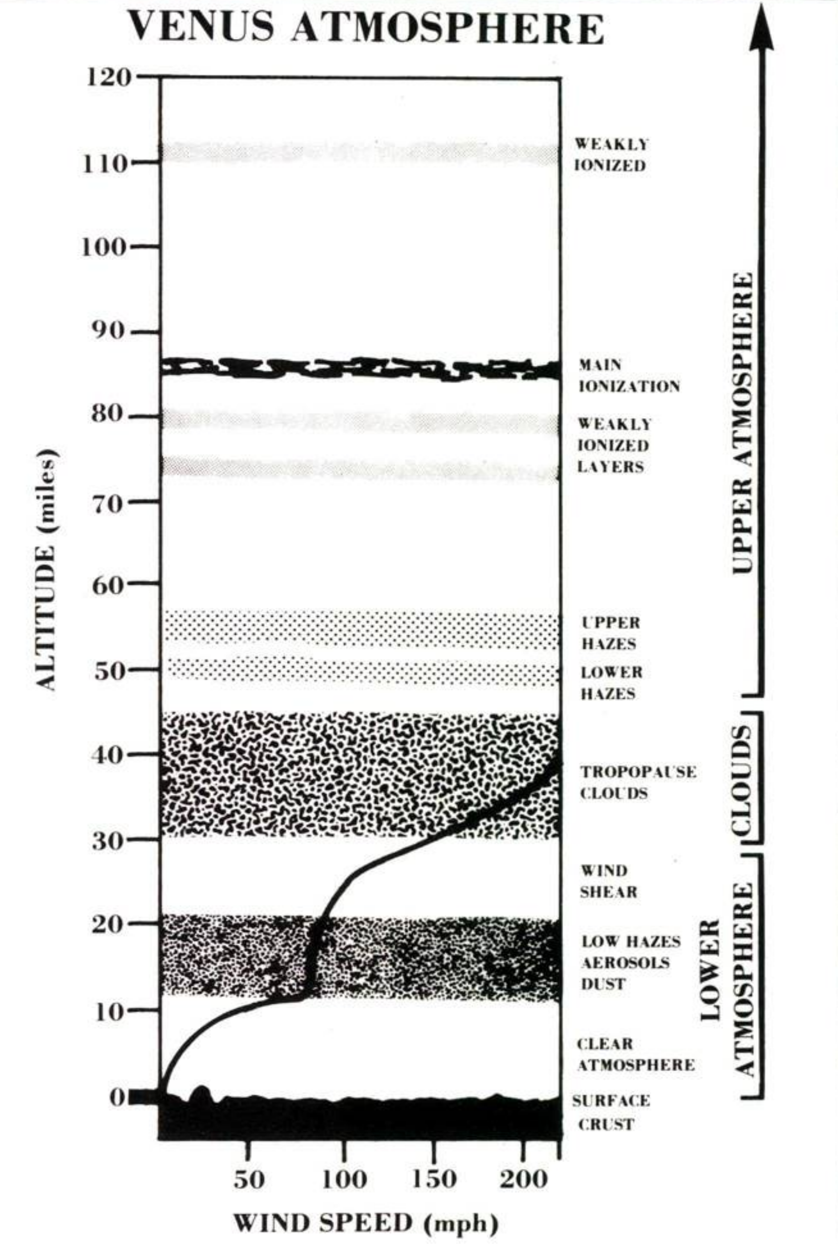
The orbiting Pioneer will circle the planet in a long ellipse, ranging from 40,000 miles out to within 100 miles of the surface. Its planned lifetime is one Venusian year (eight months in Earth time). Soon after this period has elapsed, Venus will pass behind the sun as viewed from Earth, thus cutting off radio contact for several days.

An extended mission is possible after this date, and it would be desirable to refine more closely tracking data and to search for any seasonal cycles in Venusian climate or weather. Such cycles must be very subtle, if they exist at all, since the orbit of Venus is almost perfectly circular and its axis of rotation is inclined only six degrees (it doesn't rotate very fast either).

One geodetic prize that will be sought is evidence of some longitudinal assymetry of mass, the kind of inertial imbalance that would allow tidal effects to be felt. This is connected with what otherwise would have to be considered a million-to-one coincidence: Whenever Venus is closest to Earth, the same side faces Earth. Since Venus spins twice on its axis during one Earth-Venus synodic period (the time between closest approaches), the near side is also facing Earth when Venus is on the far side of the sun, farthest from Earth.

Beyond these probes lie new possibilities: orbiters for more detailed radar imaging of the surface; floating balloons in the atmosphere (a joint Russian-French probe is scheduled to try this in 1983); longer-lived surface probes, including rovers (and submarinelike swimmers?); atmospheric and surface sample returns.

The payoff is on Earth: knowledge of how planets form, evolve, and maintain (or lose) a viable biosphere. The mysteries of Venus are too fascinating and important for us to turn away, and there is too much to learn.



The atmosphere of Venus as it is currently known is shown in profile above. The heavy line charts the dramatic increase in wind speed with increasing altitude. The Pioneer missions are expected to increase our knowledge of the structure, composition and dynamics of Venus' strange atmosphere.

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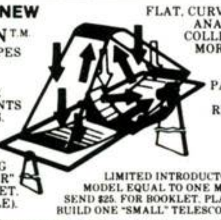

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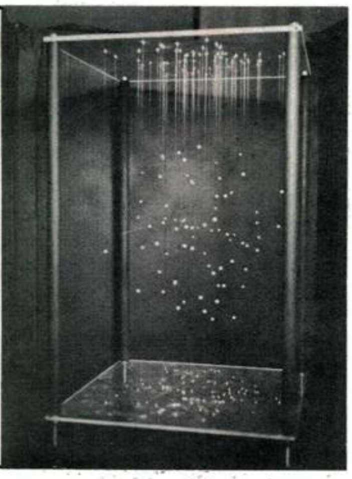

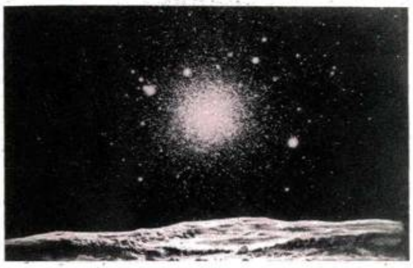

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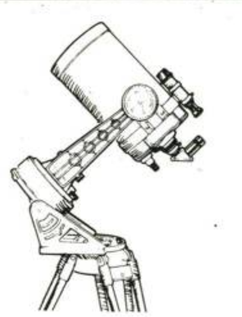

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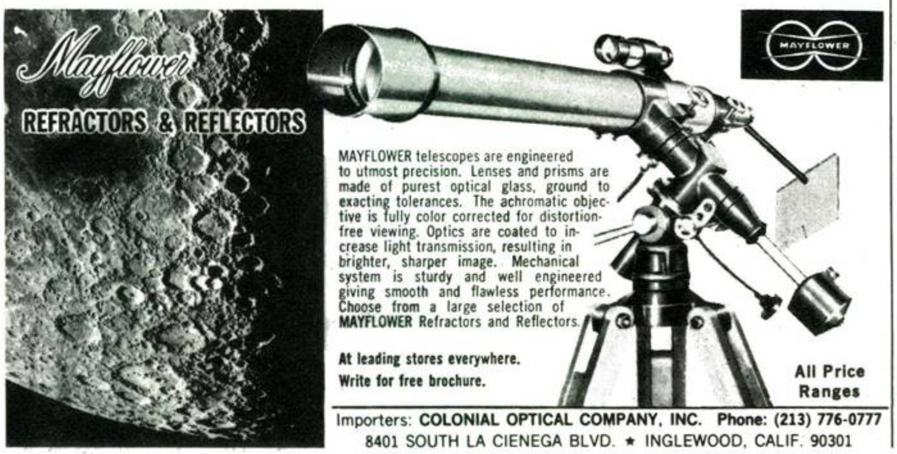

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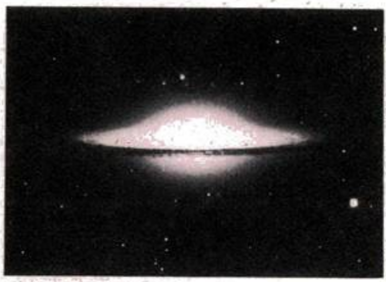
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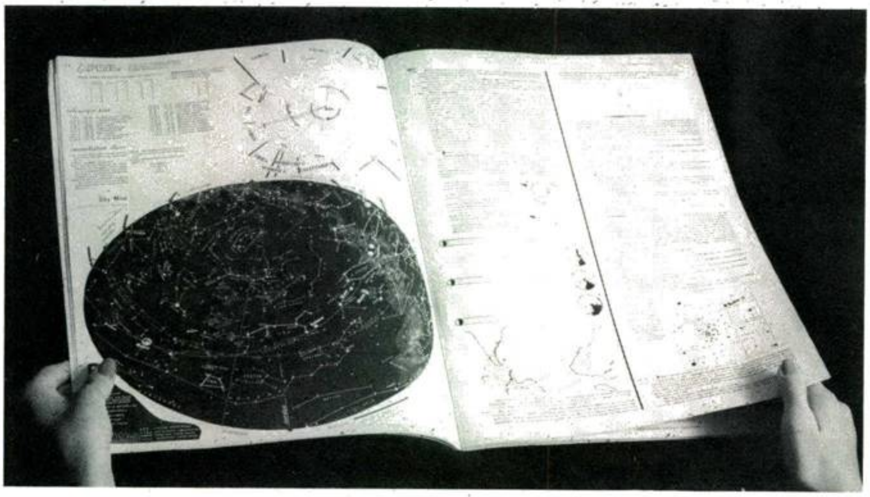

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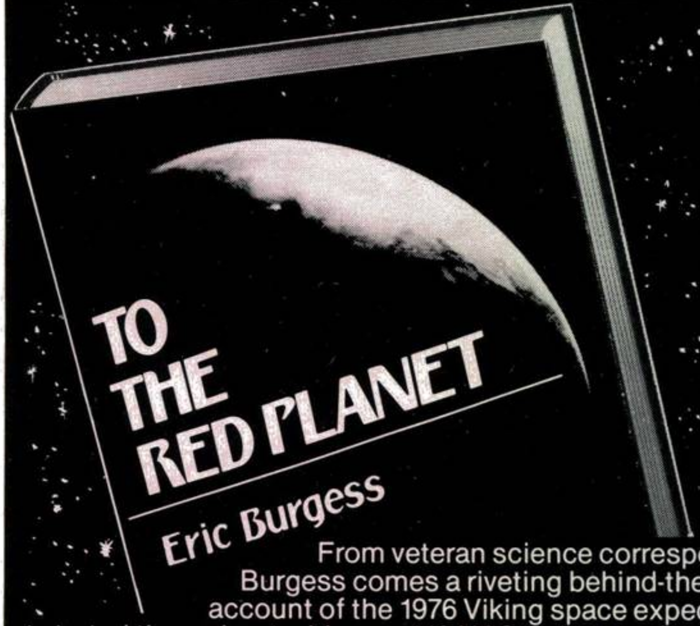

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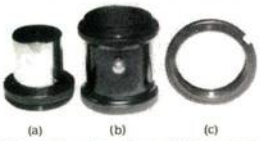

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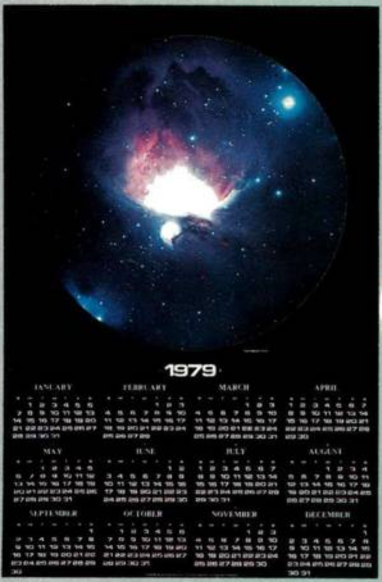

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201 North Mill Street
Holliston, MA 01746

School Street Camera
280 Washington Street
Boston, MA 02146

MICHIGAN

Birmingham Camera
168 S. Woodward
Birmingham, MI 48011

DOAA Enterprises
4610 Delemere Blvd.
Royal Oak, MI 48073

Feldman Camera Exchange
300 Oak St.
Wyandotte, MI 48192

Precision Telescope Center
58050 Jewell Road
Washington Twp., MI 48094

University Optics
2122 E. Delhi Rd.
Ann Arbor, MI 48106

MINNESOTA

Duluth Camera Exchange
321 West Superior St.
Duluth, MN 55802

E & W Optical
2420 E. Hennepin Ave.
Minneapolis, MN 55413

Virginia Boat & Sporting Dist.
205 5th Ave., So.
Virginia, MN 55792

MONTANA

AMC Sullivan Photo
107 East Main
Bozeman, MT 59715

NEBRASKA

Rockbrook Camera Center
11032 Elm Street
Omaha, NE 68144

NEVADA

Hobby House
2009-11 East Charleston Blvd.
Las Vegas, NV 89104

2001 Odyssey Shop
MGM Grand Hotel
3645 Las Vegas Blvd., So.
Las Vegas, NV 89109

Univ. of Nevada/Reno
Planetarium Gift Shop
Reno, NV 89557

NEW JERSEY

Dover Photo Supply
25 E. Blackwell St.
Dover, NJ 07801

Ridgewood Camera
48 E. Ridgewood Ave.
Ridgewood, NJ 07450

Tuthill, Roger
11 Tanglewood Lane
Mountainside, NJ 07092

NEW YORK

47th Street Photo, Inc.
67 W. 47th Street
New York, NY 10003

Hirsch, Edwin
Lake View Dr.
Tomkins Cove, NY 10986

Johnson's Studio & Camera
3208 Erie Blvd.
De Witt, NY 13214

Main Camera Center
66 Franklin St.
Rochester, NY 14604

Stangert Corp.
94 Long Beach Rd.
Island Park, L.I., NY 11558

Vernonscope
5 Ithaca Rd.
Candor, NY 13743

OHIO

Center of Science & Industry
280 E. Broad St.
Columbus, OH 43215

Dodd's Camera
7795 W. Ridgewood Dr.
Parma, OH 44129

Fairborn Camera
14 E. Main
Fairborn, OH 45324

J & R Optics
2829 Lakewood Drive
Columbus, OH 43229

Lakewood Camera Shop, Inc.
14815 Detroit Avenue
Cleveland, OH 44107

OREGON

Conkling, Inc.
4929 N. E. Fremont
Portland, OR 97213

Oregon Museum of Science
& Industry
4015 S.W. Canyon Rd.
Portland, OR 97221

PENNSYLVANIA

Astro-Marts
4801 McKnight Rd.
Pittsburgh, PA 15237

The Cameracraft Shop, Inc.
29 E. State St.
Newtown, PA 18940

(The) Camera Shop
1420 11th Ave.
Altoona, PA 16601

Carman's
4209 Edgemont Ave.
Brookhaven, PA 19015

Esman's Good Luck Dist.
560 Broadway
Pitcairn, PA 15140

Mid City Camera Exchange
1316 Walnut St.
Philadelphia, PA 19107

The Naturalist
1339 Fruitville Pike
Lancaster, PA 17601

Uptown Sales, Inc.
33 N. Main St.
Chambersburg, PA 17201

Young's Art Supply
35 Brookline Blvd.
Havertown, PA 19083

TENNESSEE

Cygnus Instruments
211 37th Ave., N. #4
Nashville, TN 37209

Electronics Ltd.
2816 White Oak Drive
Nashville, TN 37215

TEXAS

Bill Weaver Sporting Goods
3515 W. Vickery
Fort Worth, TX 76107

Burke Baker Planetarium
5800 Carolyn St.
Hermann Park
Houston, TX 77004

Don Casey Co.
229 Garvon
Garland, TX 75040

Hidalgo Supply
11246 S. Post Oak Rd.
Suite 308
Houston, TX 77035

Keaton Kolor
3520 N. 6th St.
Abilene, TX 79603

Pampa Photo
1820 N. Hobart
Pampa, TX 79065

Sigma Engineering Co., Inc.
Box 5285 (Airport Ind. Area)
Lubbock, TX 79417

Studer's Photo
146 Stribling
San Antonio, TX 78292

Texas Nautical
3209 Milam St.
Houston, TX 77006

Total Camera, Inc.
5247 Langfield
Houston, TX 77040

UTAH

Allen's Camera
36 N. University
Provo, UT 84601

Hammond Hobby
4835 Highland Drive
Lower Cottonwood Mall
Salt Lake City, UT 84117

Hammond Tots & Toys
1102 Fort Union Blvd.
Family Center
Murray, UT 84117

Hansen Planetarium
15 S. State St.
Salt Lake City, UT 84111

VIRGINIA

Dumaurier Co., Inc.
3400 Atlantic Avenue
Virginia Beach, VA 23451

Horizon Telescope
3749 Kings Pt. Road
Virginia Beach, VA 23452

John's Camera Corner
206 Draper Road
Blacksburg, VA 24060

WASHINGTON

B. E. Meyers & Co.
2717 200th Ave. S.E.
Issaquah, WA 98027

(The) Camera Shop
1003 Pacific Ave.
Tacoma, WA 98402

Clyed's Camera
1410 4th Ave.
Seattle, WA 98101

The Crescent
710 West Riverside
Spokane, WA 99201

Tobey's Photofinishing
1304 Cornwall
Bellingham, WA 98225

WISCONSIN

Wack Electronics
5722 West North Ave.
Milwaukee, WI 53208

PUERTO RICO

Mundo de Juguetes & Hobby Shop
Ave. San Carlos, Esq. Betances
Altos Coop de Credito
Aguadilla, Puerto Rico 00603

CANADA

Brooks Supplies Ltd.
1031 Robson St.
Vancouver, B. C.
Canada V6E 1A9

Centennial Planetarium
P.O. Box 2100
Calgary, Alberta,
Canada T2P 2M5

Efstonline, Inc.
3500 Bathurst St.
Toronto, Ontario
Canada M6C 2C6

Focus Scientific Ltd.
409 Rideau Street
Ottawa, Ontario
Canada K1N 5Y9

Island Colour Labs, Ltd.
615 Fort Street
Victoria, B.C.
Canada V8W 1G1

Jovian Scientific
1654 Granville Street
Halifax, Nova Scotia
Canada B3J 1X4

Lewis Instruments Ltd.
1438 Erin St.
Winnipeg, Manitoba
Canada R3E 2S8

Manitoba Museum of Man
& Nature
190 Rupert Ave.
Winnipeg, Manitoba
Canada R3B 0N2

Museum Planetarium Shop
1100 Chestnut St.
Vancouver, B.C.
Canada V6J 3J9

Paleosystems
Queen Charlotte Is. Museum
Skidegate, British Columbia
Canada V0T 1S0

Queen Elizabeth Planetarium
Coronation Park
Edmonton, Alberta
Canada T5J 0K1

Tele-Optics
2026 8th Ave., S.E.
Calgary, Alberta
Canada T2G 0N8

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8/1/78

STAR DOME

DECEMBER

by

James Mullaney and Dewey Schwartzenburg

December is the dark month, the month of night. It brings us the longest night of the year and also the night of the earliest sunset (though not the night of the latest sunrise, which occurs in early January). Strangely, these three nights do not coincide. The sun sets at its earliest this year on Dec. 7, while the longest night of the year occurs, of course, on the winter solstice, Dec. 22. Even though the sun sets earlier on the 7th than on the 22nd, it rises the next morning still earlier, making the night a little shorter than that of the 22nd.

But the difference in times of sunset is very small, amounting to only a few minutes. It is the solstice on Dec. 22 which has captured human imagination through the ages: the day which John Donne called "the yeares midnight", when the sun reaches its southernmost point and begins its six month journey to the north. December may be the darkest month, and the solstice the midnight of the year, but for that very reason December and its solstice in particular have been a time of festive celebration in nearly all cultures, past and present.

In 1978, Christmas day coincides with the first day of Hanukkah (or Chanukah — the first consonant is a gutteral sound unknown in English). This doesn't always happen because although Christmas day is a fixed calendar date (Dec. 25), Hanukkah is determined according to the Jewish calendar, a lunar calendar modified by the solar year (so that the months do not fall too far out of line with the seasons, which would happen with a purely lunar calendar like that of Islam). Hanukkah, an eight day celebration, begins on the 25th day of the Jewish month roughly corresponding to December. Since the new moon, always the first day of a Jewish month, occurs this month on the night of Nov. 30 - Dec. 1, the 25th of both the Jewish and secular months coincide.

Hanukkah, also called the Festival of Lights, commemorates the cleansing and rededication of the Temple in Jerusalem by the Maccabees in the second century B.C. In comparison with other Jewish festivals such as Rosh Hashanah and Passover, it is of relatively minor importance, but because of the Christian feast of Christmas occurring about the same time, it has assumed greater significance.

Ironically, Christmas itself first came about because of a similar "competition" over the winter solstice! Christmas day, in observance of the birth of Jesus, is not actually a very ancient festival for Christians. It only made its appearance toward the end of the third century A.D., when it began to be observed by Christians to compete with a new pagan festival (introduced by the Roman Emperor Aurelian) called the Birth of the Unconquered Sun. Aurelian, a violently anti-Christian emperor at a time when Christianity seemed about to take over the empire, attempted to revive the flagging pagan religious system by introducing a new supreme deity into the pantheon — the sun. The highest holy day of this new imperial religion was to be the feast of the Birth of the Unconquered Sun (Sol Invictus), set to fall on the very day of the winter solstice — which at that time was Dec. 25. On that day the sun, which had been sinking ever lower in the sky causing shorter and shorter days, began to ascend, born anew and unconquered by the forces of darkness.

The Christians quickly countered this clever public relations ploy with one of their own, inaugurating on the same day an observance of the birth of their "unconquered Son" — Jesus. (The pun in English, though absent in Latin, does occur more as a rhyme than as a true pun in Greek.)

Actually it is more likely that Jesus was born around the time of the spring equinox, for the Gospel of Luke states that at the time of Jesus's birth, shepherds were out in the fields "keeping watch over their flocks by night". Well, no shepherd in his right mind spends *every* night in the fields with a bunch of sheep — except in the early spring when the ewes are giving birth to their lambs. And in fact there is a very ancient tradition holding that Jesus was born on the very same date he died — and that both days were spring equinoxes.

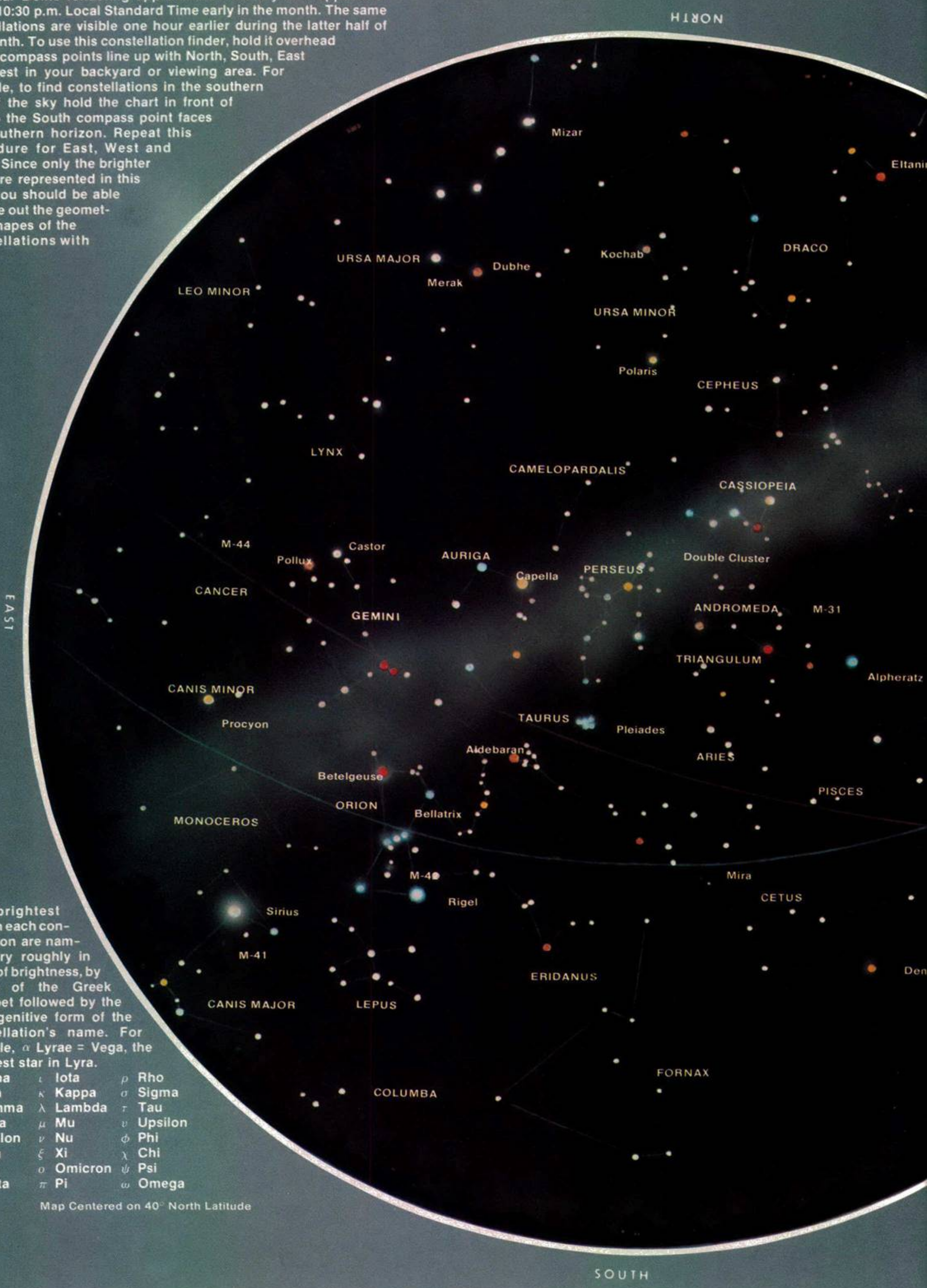
Thus the pagan, anti-Christian Emperor Aurelian, ironically, is responsible for both the observance and date of Christmas. His attempt at a solar religious reform failed as completely as the one mounted in Egypt centuries before by Pharoah Ikhnaton (or Akhenaton — or Akhenaten — they couldn't spell very well in those days).

We might add here that the oft-repeated tale connecting Christmas with the local Roman festival of Saturnalia has no basis in fact. Saturnalia was a much earlier and more minor observance than that of Sol Invictus; it was never celebrated much outside of Italy, and presented little threat to Christianity. But Aurelian, with his anti-Christian campaign, was an entirely different matter!

Christmas proved to be very popular, and so it has continued to our own time — even though it is actually of much less religious significance for Christians than the feasts of Easter day and Pentecost (the 50th and final day of the Easter celebration). No doubt this is because something profoundly deep and moving in the human psyche is touched by a celebration at the time of the winter solstice.

All these festivals we've mentioned — Saturnalia, Sol Invictus, Hanukkah and Christmas, as well as others such as the ancient Teutonic feast of Yule — are associated in some way with the winter solstice. And all involve the

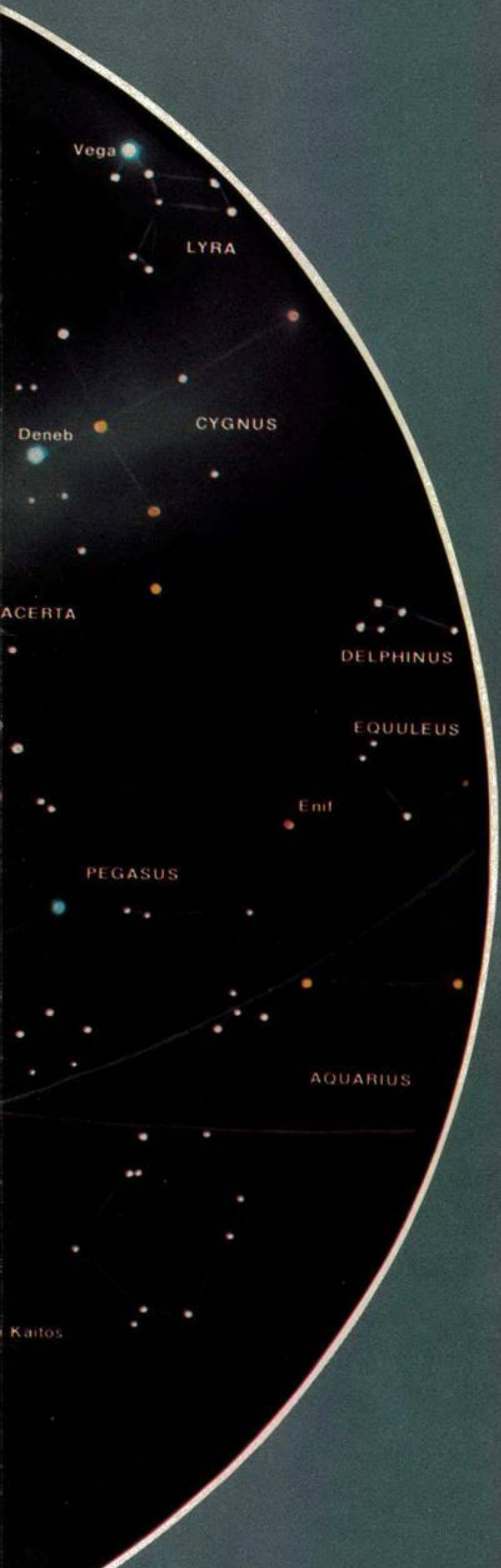
This Star Dome rendering approximates the sky as it appears at about 10:30 p.m. Local Standard Time early in the month. The same constellations are visible one hour earlier during the latter half of the month. To use this constellation finder, hold it overhead so the compass points line up with North, South, East and West in your backyard or viewing area. For example, to find constellations in the southern part of the sky hold the chart in front of you so the South compass point faces the southern horizon. Repeat this procedure for East, West and North. Since only the brighter stars are represented in this map, you should be able to trace out the geometrical shapes of the constellations with ease.


NORTH
Mizar
Eltani
DRACO
URSA MAJOR
Dubhe
Kochab
Merak
LEO MINOR
URSA MINOR
Polaris
CEPHEUS
LYNX
CAMELOPARDALIS
CASSIOPEIA
M-44
Castor
AURIGA
Pollux
Double Cluster
Capella
PERSEUS
CANCER
EAST
GEMINI
ANDROMEDA
M-31
TRIANGULUM
Alpheratz
CANIS MINOR
TAURUS
Procyon
Pleiades
Aldebaran
ARIES
Betelgeuse
PISCES
ORION
Bellatrix
MONOCEROS
M-4
Mira
CETUS
Rigel
Sirius
M-41
Den
ERIDANUS
CANIS MAJOR
LEPUS
FORNAX
COLUMBA
SOUTH

The brightest stars in each constellation are named, very roughly in order of brightness, by letters of the Greek alphabet followed by the Latin genitive form of the constellation's name. For example, α Lyrae = Vega, the brightest star in Lyra.

α	Alpha	ι	Iota	ρ	Rho
β	Beta	κ	Kappa	σ	Sigma
γ	Gamma	λ	Lambda	τ	Tau
δ	Delta	μ	Mu	υ	Upsilon
ε	Epsilon	ν	Nu	φ	Phi
ζ	Zeta	ξ	Xi	χ	Chi
η	Eta	ο	Omicron	ψ	Psi
θ	Theta	π	Pi	ω	Omega

Map Centered on 40° North Latitude



Map by Adolf Schaller

theme of light triumphing over darkness. In our modern world, where electricity has banished darkness from night so successfully, it is hard for us to appreciate the impact of a day like the winter solstice. The emotions of the medieval monks who sang at Vespers, "Night comes with all its Darkling Fears/Regard thy people's prayers and tears", are strange and foreign to us in our glittering illuminated cities and watt-infested homes.

With the decline of an awareness of night and its associated fears has come a lack of appreciation of its beauty and wonder, so much a part of our ancestors' lives. Most people today would have no idea what phase the moon is in without looking it up. (Hopefully our readers do! Can you tell without turning to Sky Almanac?) Even astronomy enthusiasts sometimes forget to lay book and telescope aside once in a while, and simply gaze up at the magnificent dome of the night sky in pleasure and appreciation. While Star Dome's Close-Up guides us to the wonders to be seen in small telescopes in a particular constellation, this introduction to each month is devoted to naked eye contemplation and understanding of the night sky. Here we seek to increase the pleasure of this too-often neglected aspect of astronomy both by exploring the tales and myths of the past, and expounding the knowledge of the present.

The night sky is waiting for those of us who can perceive still another reason for celebrating the winter solstice — the longest night of the year. Why not have a "holiday star party" this year on Dec. 22 to commemorate it?

Close-Up

Auriga Region

Auriga is known as the charioteer, though strangely all the traditional representations of this winter constellation depict instead what is obviously a goatherd. Undoubtedly we have here the relic of some ancient divergence as to what this pattern of stars represents, but the details are lost in obscurity.

A more modern name might be the pentagon, for the familiar pattern of five relatively bright stars is immediately recognizable as such. One of the five, El Nath, actually belongs to the constellation Taurus, according to the boundaries adopted by the International Astronomical Union in 1930. When Bayer assigned Greek letters to the stars of the various constellations (see Star Dome, September 1977), he solved the problem of which constellation El Nath belonged to by giving it a letter in both! Thus El Nath is known as either Beta (β) Tauri or Gamma (γ) Aurigae, though with the present boundaries the former name is preferred.

The brightest star in Auriga is Capella, also known as "the goat" because it traditionally marked the location of a goat held by the goatherd. It is probably a she-goat, for immediately below are her "kids" — Epsilon (ϵ), Zeta (ζ) and Eta (η) Aurigae — famed among ancient sailors as sinister harbingers of ocean storms. More than 2,000 years ago a poet wrote, "Tempt not the winds forewarned of dangers nigh/When the Kids glitter in the evening sky." Ancient mariners knew it wasn't safe to venture from harbor until Capella and the kids vanished below the western horizon months later, in the spring.

Capella

The lucida of Auriga is zero magnitude Capella. This golden yellow gem lies closer to the north celestial pole than any other bright star, and is visible to midnorthern latitude observers at some hour every clear night of the year. It ranks sixth in order of luster of all the stars in the heavens. As Eudosia expressed it: "And scare a star with equal radiance beams/Upon the earth."

Capella is a well-known spectroscopic binary made up of a G type primary and F type secondary revolving about each other in a period of 104 days. Although suspected of having been elongated visually in large observatory refractors, this dynamic duo appears as only a single radiant sun in common telescopes. The prismatic flickering of this star, so evident to the eye on turbulent nights as it is rising or setting, is even more striking in the telescope — especially with the eyepiece thrown well out of focus!

There are a number of faint telescopic stars surrounding Capella, at least one of which is moving through space with it. This is a 10th magnitude red dwarf binary (three seconds of arc separation), 12 minutes to the southeast. Concerning the space motion of the great star itself, Robert Burnham Jr. of Lowell Observatory pointed out that it "closely matches that of the Taurus moving group associated with the Hyades star cluster and Capella may be an outlying member of the group".

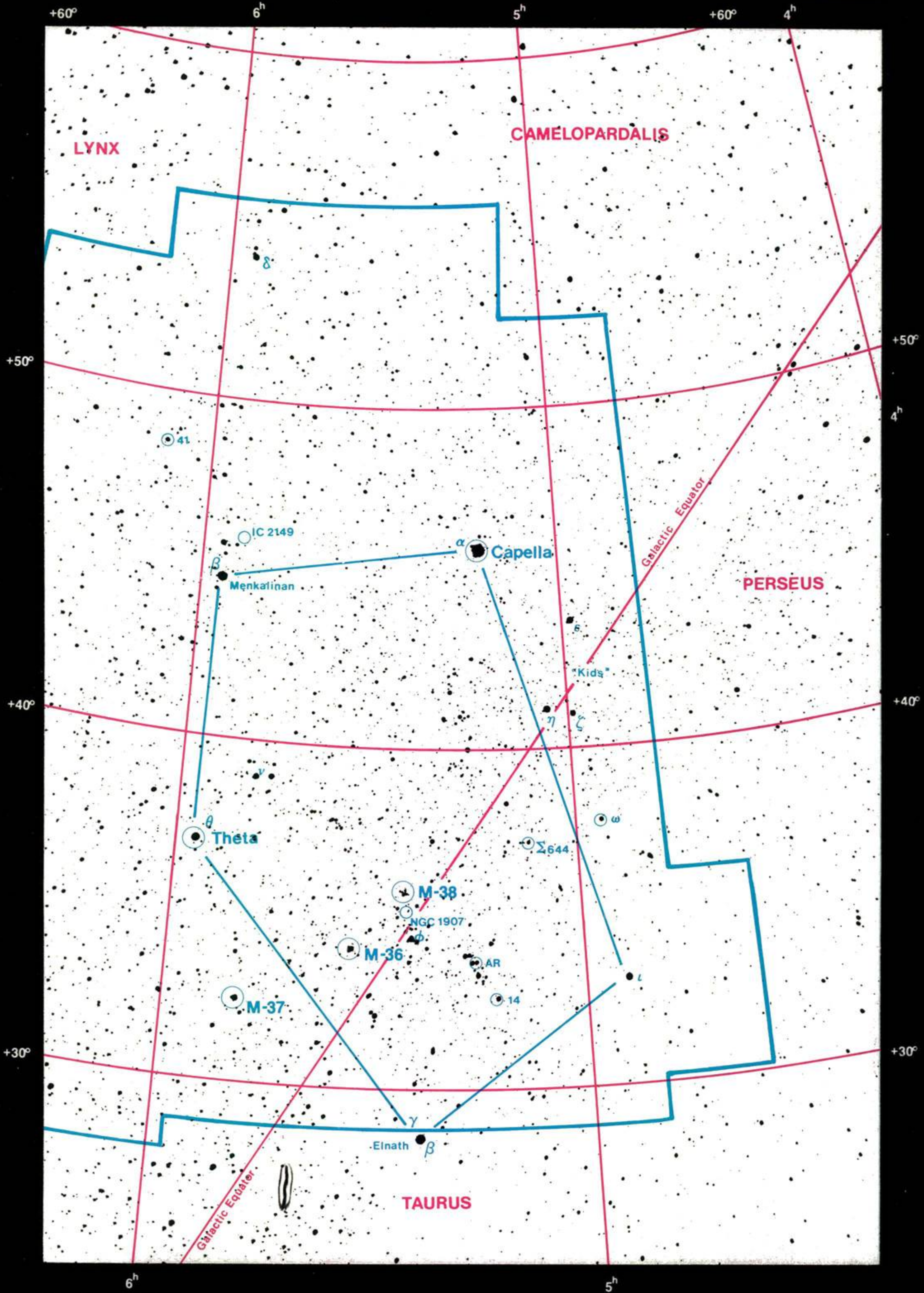
The warm light of the lovely sun we see tonight left the Capella system in 1933 and has been traveling through interstellar space for nearly a half century to reach us.

Theta (θ) Aurigae

This month's region is well stocked with attractive and colorful double

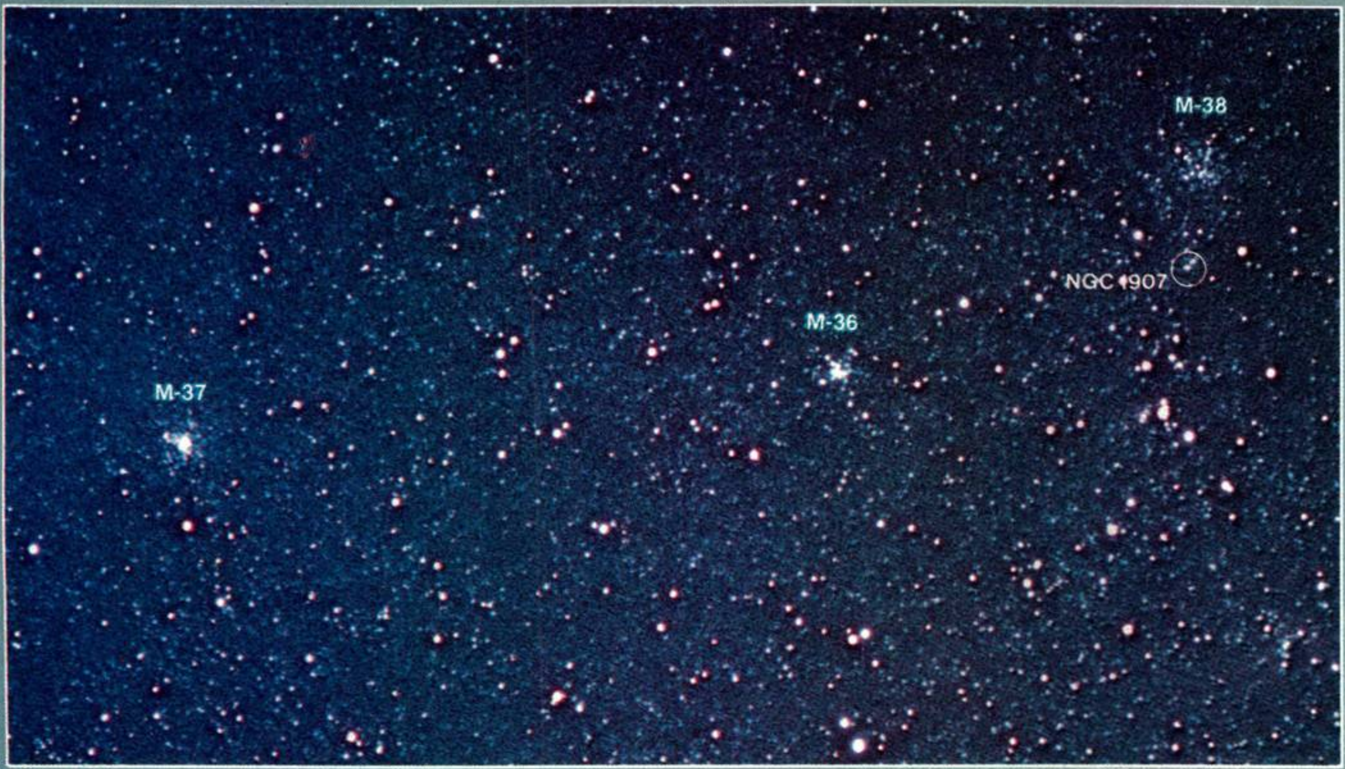
AURIGA

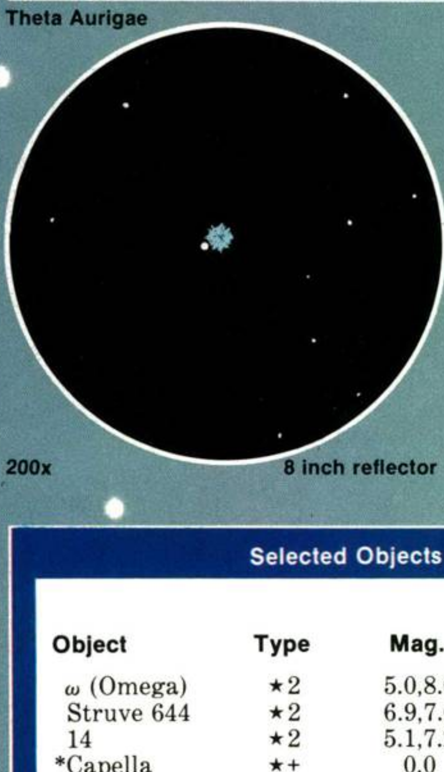
Epoch 1950 coordinates


+60°
6h
5h
+60°
4h
LYNX
CAMELOPARDALIS
δ
+50°
+50°
4h
41
IC 2149
α
Capella
β
Menkalinan
Galactic Equator
PERSEUS
ε
"Kids"
η
ζ
+40°
+40°
ν
θ
Theta
ω
Σ644
M-38
NGC 1907
φ
M-36
AR
ι
14
M-37
+30°
+30°
γ
Elnath
β
TAURUS
Galactic Equator
6h
5h

Map by Dewey Schwartzenburg

Photograph by Robert Provin and Brad Wallis





Above: These four open clusters found within the pentagon of Auriga are especially beautiful in small telescopes. Photograph by Leo C. Henzl Jr. Left: A particularly fine unequal double star, Theta Aurigae is difficult to split with anything less than six inches aperture. Drawing by James Mullaney.

stars for small telescopes, some of the more interesting of which are given in our accompanying table. Here we'll highlight instead a somewhat difficult yet striking duo that presents a challenge to sky, instrument and observer alike. This is Theta Aurigae, located seven degrees due south of Beta, and forming with it the eastern side of the well-known pentagon of Auriga.

Theta consists of a third magnitude primary sun and a seventh magnitude companion presently about 3.4 seconds away near position angle 320 degrees (to the northwest on the sky). Together they present a superb magnitude contrast for medium to large sized telescopes. While considered a test for a four inch instrument, you may find this pair difficult to split in anything less than a six inch on a typical night. High power and excellent seeing (image steadiness) are essential for a good view; given these, Theta is one of the finest unequal doubles in the sky through 8 to 12 inch telescopes. Our drawing with an eight inch reflector at 200 power suggests what to expect on a tranquil night.

Like its neighbor UU Aurigae, this duo has received little attention from observers, both past and present. Back in Webb's time, the two stars were only two seconds apart (and aligned nearly north-south on the sky), making them even more difficult to resolve. Theta Aurigae is a good example of an entire class of deep sky objects that are both difficult to observe and yet highly attractive at the eyepiece; among doubles, Antares and Sirius are two other cases in point.

This pair is a very slow moving binary system whose period has been estimated at seven or eight centuries, and which lies 110 light-years from us. The brighter member is a hot, blue-white B type star, and the fainter

Selected Objects — Auriga Region

Object	Type	Mag.	Size/Sep. Per.	R.A. (1950)	Dec.
ω (Omega)	★2	5.0,8.0	5″	04^h56^m	+37°49′
Struve 644	★2	6.9,7.0	1.5″	05^h07^m	+37°14′
14	★2	5.1,7.2	15″	05^h12^m	+32°38′
*Capella	★+	0.0	--	05^h13^m	+45°57′
AR	Ӿ★	5.8–6.5	4.14^d	05^h15^m	+33°43′
NGC-1907	○	9.9	5′	05^h25^m	+35°17′
*M-38	○	7.4	20′	05^h25^m	+35°48′
*M-36	○	6.3	12′	05^h32^m	+34°07′
*M-37	○	6.2	20′	05^h49^m	+32°33′
IC-2149	■	9.9	15″x10″	05^h53^m	+46°07′
*θ (Theta)	★2	2.7,7.1	3″	05^h56^m	+37°13′
41	★2	6.1,6.8	8″	06^h08^m	+48°43′

*Detailed in Close-Up

★+ = Bright Star
Ӿ★ = Eclipsing Variable
○ = Open Cluster
★2 = Double Star
■ = Planetary Nebula

one a yellow G type sun, suggesting an attractive color contrast in the telescope. Yet both stars appear bluish most nights. How do you find them in your telescope?

M-38

Of the many rich Milky Way star fields and glittering open clusters to be found in Auriga, three stand out as showpieces for the small telescope user. Discoveries of Charles Messier, they can readily be seen in binoculars and finders, and are exciting telescopic sights on dark (moonless) transparent winter nights. Despite the fact that they all belong to the same class of objects, these stellar jewel boxes each have their own distinctive features and special appeal for the visual observer.

We begin with M-38, conveniently located near the heart of the Auriga pentagon, midway between the stars Theta(θ) and Iota(ι). Sweeping there with a low power eyepiece will quickly reveal this lovely seventh magnitude clan, containing some 100 suns in an area 20 minutes of arc in size. A three inch refractor at 45 power shows its brighter units arranged in the shape of a crude "X", while six and eight inch reflectors at 40 to 60 power fill in the faint stellar background members in striking profusion.

Webb called M-38: "a noble cluster arranged as oblique cross: pair of larger stars in each arm; brighter star in center; not brighter than pairs 1871, 1877. Larger stars dot it prettily with open doubles. Glorious neighborhood." Norton described it as "a striking, loose, cruciform cluster", while Muirden found it an "extensive cluster of bright stars ranged against star dust, with a cruciform outline". Pickering recognized it as a "runner-up" to his listing under the category of irregular clusters.

Still other impressions of M-38 are to be had in the observational literature. Burnham, for example, noted: "It is a scattered group of irregular form, with the brightest stars in a pattern resembling an inverted letter 'Pi'." Messier authority Holyoke called it "a notable one for the crosslike appearance in a small telescope. The cluster is coarser than the other two (M-36 and M-37)." The NGC account reads: "Cluster, bright, very large, very rich, irregular figure, stars large (bright) and small (faint)."

M-36

Slightly more than two degrees southeast of M-38 lies the second member of the Messier trio in Auriga — M-36. It fits neatly within the field of a four inch RFT at 15 power with M-38 and NGC-1907, allowing simultaneous comparison of these three objects. Even a two inch scope at just 30 power will show the individual stars in M-36 (as well as in M-38 and M-37), but larger apertures greatly enhance the view. As Burnham pointed out, "The group makes its best impression with a low power (20x to 50x) on a six or eight inch telescope." Such a combination shows the field of view flooded with a uniform scattering of bright and faint stellar pinpoints, and individual star tints can be made out by a trained eye. At least 60 suns swell its 12 minute boundary.

Webb logged M-36 as a "beautiful assemblage of stars, 8th to 14th magnitude, very regularly arranged, two degrees following (east of) Phi (Aurigae)". Muirden saw this cluster as a "superb group of bright and faint stars", while Holyoke regarded it a "small cluster" and stated that 60 power was adequate for a good view with his six inch reflector. The NGC gave the following account: "Cluster, bright, very large, very rich, little compressed, stars from 9th to 11th magnitude, scattered."

Strangely, Pickering, Barns and Olcott did not mention M-36 at all in their works! Chambers called it "a neat cluster...with double star in field", and Bernhard, Bennett and Rice "a fine one with double star". The pair referred to in these accounts is designated Struve 737 — magnitudes eight and nine, with a separation of 11 seconds; it adds nicely to the overall beauty of the scene. Can you supplement these descriptions of this stunning stellar commune from your own personal observations at the eyepiece?

M-37

Saving the best for last, we now examine the third Messier open cluster in Auriga, and one of the finest representatives of its class anywhere in the sky. This is M-37, situated about three degrees southeast of M-36, near the midpoint of a line from Theta Aurigae to Beta Tauri (the star "borrowed" from neighboring Taurus to complete the Auriga pentagon).

A marvelous sight in anything from a three inch refractor to large observatory instruments, M-37 is perhaps at its best in medium sized reflectors at low power. The view in an 8 or 10 inch at 40 to 70 diameters is nothing less than breathtaking! This object is one of the very few members of its class rich enough to remain striking through a 13 inch refractor, with its relatively high minimum magnification and narrow field of view.

Having a combined radiance equal to that of a sixth magnitude star, M-37 contains more than 150 member suns in an area at least 20 minutes across. Some estimates of its actual population run as high as 500 stars, agreeing better with what greets the eye in a large telescope. As is frequently the case with open clusters, there is a relatively bright (ninth magnitude), ruddy orange star near its center. Where these strange stars do occur, they are of great help in critical focusing on the host of fainter surrounding suns.

So densely peppered with stars is M-37 that it reminds many observers of a globular cluster rather than an open one. As we've suggested in encountering similar objects in the past, it may well belong to a type intermediate between the two classes — one that is sometimes called "semiglobular". In adding this swarm to his compilation as another runner-up object, Pickering actually listed it as a globular cluster. It's easy to see how he arrived at the latter assessment, but certainly not the former — in no way can this grand stellar assemblage be thought of as second rate! Why not have a look with your scope the next clear night and see for yourself?

Smyth's impression of M-37 was: "A magnificent object: the whole field being strewed, as it were, with sparkling gold-dust; and the group is resolvable into about 500 stars, from 10th to 14th magnitude, besides the outliers". His observations were made with a six inch refractor and accurately describe what a trained observer can expect to see on a good night with a modern six or eight inch reflector.

Combining direct observation at the eyepiece with keen deductive reasoning, Webb set an example for all of us in his log of M-37: "Even in smaller instruments extremely beautiful, one of the finest of its class. Gaze at it well and long. Knott notices a brighter star near center, Burton: ruby: 10th magnitude, Espin: 9th magnitude: pale red. All the stars in the mass must be nearly at the same distance from us, and consequently their real sizes must be different...it is ocular proof of the incontrovertible, though long discredited fact, that the apparent brightness of stars has very little connection with their distance from Earth. Earl of Rosse, wonderful loops and curved lines of stars, first remarked by D'Arrest." This was written at a time when little was known about the actual physical nature of the stars themselves.

Like its two Messier neighbors, M-37 lies between 4,000 and 5,000 light-years from us, embedded in the glowing stratum of the winter Milky Way. Set against this rich stellar backdrop, the sight of this misty heavenly host evokes in many observers thoughts and feelings that border on the spiritual. Perhaps this is not surprising, for as Abraham Lincoln stated: "I never behold the stars that I do not feel that I am looking in the face of God."

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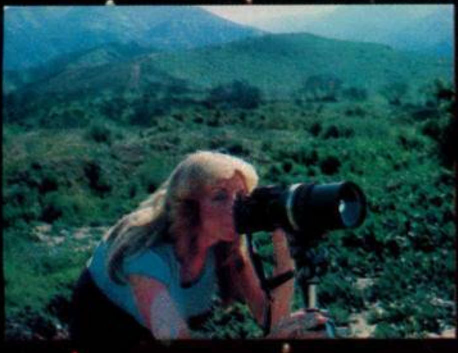

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